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A GEOLOGICAL AND GEOPHYSICAL INFORMATION SYSTEM FOR EURASIA, THE MIDDLE EAST AND NORTH AFRICA

DIGITAL DATABASE DEVELOPMENT FOR THE MIDDLE EAST AND NORTH AFRICA

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With the anticipated completion of multilateral comprehensive nuclear test ban and nonproliferation treaties in the near future, it is essential for the monitoring ef-forts that multidisciplinary information on any given re-gion is readily available and accessible in a digital, on-line format via electronic networks for use by concerned re-searchers and decision makers. Our objective is to collect and orga-nize all available seismological, geophysical, and geological datasets for the Middle East and North Africa into a digital information system that is accessible via the Internet from Cornell and can be utilized by the International Data Center and by other ARPA/AFOSR/DOE/AFTAC researchers. We have begun with the depth of the Moho and basement and crustal velocity and density structures, primarily as interpreted from seismic refraction, gravity, and drill hole datasets. We have completed data from Egypt, Iran, Iraq, Israel, Jordan, Syria, Lebanon, and Saudi Arabia. We have also digitized key geologic features for the Middle East. All data are being stored in our Arc/Info Geographic Information System. We are maintaining a com-prehensive bibliography of all the relevant references in a computer database. We are releasing preliminary versions of these databases in several different forms. Our Web address is "http://www.geo.cornell.edu/geology/me_na/main.html".

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1. INTRODUCTION

Crustal and lithospheric structure variations as well as major topographic relief along seismic wave propagation paths and at the source and receiver sites are crucial information to understand the excitation and propagation of high-frequency regional seismic phases, and other aspects of the problems of verification and estimation of the yield of nuclear and chemical explosions. Our objective is to collect and organize all available seismological, geophysical, topographical, and geological datasets for the Middle East and North Africa into a digital information system that is accessible via the Internet from Cornell and can be utilized by display programs running at the Center for Monitoring Research (CMR) and by other ARPA/AFOSR/DOE/AFTAC researchers.

We have begun a comprehensive effort to compile and digitize information on the crustal structure of the Middle East and North Africa to expand our existing database for Eurasia developed under previous contracts. Our first work has been in the Middle East where we are locating and digitizing published data on the depth of the Moho and basement and crustal velocity and density structures, primarily as interpreted from seismic refraction, gravity, and drill hole datasets. We are also maintaining a comprehensive bibliography of all the relevant references in a computer database. All data are being stored in our Arc/Info Geographic Information System (GIS), the most widely used full-featured GIS. The format of the files being released is detailed in Appendix I.

2. DIGITAL DATABASE DEVELOPMENT FOR THE MIDDLE EAST AND NORTH AFRICA

Our first Release #1 of October 1993 (see Appendix II) detailed the priority list for our database development, and this is our first release of preliminary datasets. We are continuing to add more information to our database and plan to issue further interim releases as we progress toward our goal of a complete crustal structure database as well as other types of geophysical and geological databases for the Middle East and North Africa. We hope that these interim releases will be

useful to and used by other ARPA/AFOSR/DOE/AFTAC researchers studying the propagation of seismic phases in the Middle East and North Africa. In this first data release, we present some of the data interpretations country by country, including Egypt, Iran, Israel, Jordan, and Saudi Arabia. In the future, we will be integrating these individual observations and our own analyses into a regional gridded database of the best available information on crustal structure and velocities. This database can then be used to derive crustal structure profiles along any path through the region to compare with observations or simulate the propagation of regional seismic phases as described in the final report of our previous contract (Fielding and others, 1993).

2.1. Geophysics

A number of seismic refraction lines of various types have been shot in many of the countries of the region. We are digitizing the locations of the lines, the interpreted sections, and the velocity-depth profiles from published papers. We also digitize the interpreted contours of the depth of Moho or other crustal boundaries where they are included in the published works. Several gravity interpretations of crustal structure have also been published in the Middle East and we are digitizing the interpreted sections and contour maps of Moho in a manner similar to that of the refraction data. A map showing the Middle East refraction and gravity profiles included in this release and several others that will be included in future releases is shown in Figure 1.

2.1.1. Gravity

From gravity interpretation publications, we digitize the locations of the profiles of crustal density structure from the location map and convert them to latitude-longitude coordinates. We then digitize the major crustal interfaces of the gravity interpretation profiles and convert the lines to distance-depth coordinates in km, with distance measured from the "zero" origin chosen by the authors and depth negative below sea level. Each "arc" or interface is then assigned "attributes" that indicate the density above and below the interface (stored in the

Arc Attribute Table or AAT in Arc/Info). The profile and map data, including the interfaces and associated attributes, are brought into Adobe Illustrator for minor editing and labeling to produce final figures, such as Figure 1.

2.1.2. Refraction

We digitize seismic refraction results from publications in a similar way. The locations of the receiver lines and shot points are digitized and converted to latitude-longitude geographic coordinates. The interfaces of interpreted refraction profiles available are digitized and converted into distance-depth coordinates in km. Then attributes are assigned to each interface to store the velocities above and below the interface in the AAT. We keep the same distance origin used by the authors, which is usually taken to be the location of a shot used for ray-tracing the 2-D velocity model. We also digitize 1-D velocity-depth functions by tracing the lines of figures and then convert them to velocity and depth coordinates in km/sec and km, respectively.

Contour maps of depth of the Moho or other crustal structures are digitized in Arc/Info by recording the depth value of each contour as an attribute of the "arc" or contour line. As for all maps, the locations are converted to geographic coordinates by taking known points and estimating the proper map projection parameters to invert the projection used in making the map.

These contour datasets are then converted into grids by using the topogrid command of Arc/Info software. Topogrid uses an iterative finite difference interpolation technique. Based upon the ANUDEM program developed by Hutchinson (1989), this procedure is specifically designed for creating hydrologically correct digital topography. However, it can be used for other purposes like gravity grids without drainage restrictions by turning the drainage enforcement off.

2.2. Geology

Our first efforts under this project have concentrated on geophysical data on crustal structure, but we plan to add more geological data in the future. Many geologic maps and information on stratigraphy and structure from sources such as drill holes are available throughout the Middle East and North Africa. These data will be useful to better understand the tectonic structure and development of the region, and especially useful for mapping the distribution of special geologic units such as salt beds that have a large effect on the generation or propagation of seismic signals. A few of the major tectonic features in the Middle East have been digitized at a relatively crude scale suitable for regional maps and are shown on some of the figures in this report.

2.3. Satellite Imagery

Under other projects at Cornell, we have acquired some digital satellite imagery for areas of the Middle East, North Africa, and Eurasia. The most extensive coverage are complete sets of Landsat Multispectral Scanner (MSS) images for Syria and Morocco. A big advantage of Landsat MSS scenes is that they are not copyrighted and are freely shareable with other researchers.

2.4. Seismicity and Focal Mechanisms

The hypocenters located between 50°N 10°S and 70°E 20°W, were extracted from two different sources: the International Seismological Center (ISC) and the United States Geological Survey (USGS). The catalog from the ISC includes events from January 1964 trough August 1987, while the one from the USGS includes events from 2000 B.C. through December 1990. Each event in the data base is described according to date, time, latitude, longitude, magnitude, depth, intensity and associated phenomena. An Arc/Info coverage has been generated from the USGS data base (Figure 2a) and the characteristics of each event have been included as separate items in the point attribute tables (.PAT) for this coverage. In the future, the ISC data base will be converted into an Arc/Info

coverage. We also plan to create a more comprehensive and complete catalog of earthquakes in the region. Figure 2b shows the Harvard database of focal mechanism solutions in our region. A more complete focal mechanism catalog will be developed based on all available literature.

2.5. Explosions

The USGS/NEIC data base includes identified explosions. All the explosions in the Middle East and North Africa region are extracted from the Arc/Info coverage and shown in Figure 3. There are other explosion sites in the region. In future releases we will provide a map of large industrial explosion sites in the Middle East and North Africa.

2.6. Bibliography

We are building our bibliographic database (see Appendix III) in the Macintosh program called HyperCard (which comes bundled with every Macintosh). References to books, journal articles, reports and other published literature are stored with the usual information on title, date, authors, journal, page numbers, etc. and with searchable keywords on the content. Automatically (by keyword search) or manually selected subsets of the HyperCard dataset can be extracted and formatted in a variety of formats. This is becoming a comprehensive database of crustal structure, geology, and geophysics literature for the Middle East and North Africa, and we have copies of nearly all the references, including many hard-to-find reports, in our files. We continue to add to this bibliographic database, but we are releasing this preliminary version now to aid other researchers.

3. STATUS OF DATABASES

3.1. Eurasia

All of the crustal structure databases produced for Europe and Asia under our previous contracts continue to be available via "anonymous ftp" and our raster server. We continue to fill requests for these databases from seismic researchers around the world under ARPA/AFOSR/DOE/AFTAC contracts.

3.2. Middle East

3.2.1. Egypt

Both gravity and deep seismic refraction data have been collected in Egypt. A dissertation by Marzouk (1988) describes much of the data.

We digitized a contour map of the depth to the Moho that is based on gravity and refraction data (Figure 4). We also digitized a contour map of Bouguer gravity anomalies of this area. Grids have been built by using the topogrid command of Arc/Info.

Most of Egypt has crust 30-33 km thick, but it thins dramatically in the Red Sea rift zone to 20 km or less. Only the beginning of the crustal thinning of the Red Sea rift is shown in Figure 4. Southern and western Egypt has thicker crust reaching more than 35 km, while the northernmost part of Egypt includes part of the transition into the Mediterranean oceanic crust with crust down to 27 km thick at the coastline. The sediment thicknesses increase gradually to the north in Egypt where the large delta of the Nile extends into the Mediterranean.

3.2.2. Iran

We have begun our database for Iran with the digitization of the crustal structure profiles interpreted from gravity data by Snyder and Barazangi (1986). The locations of the three profiles of crustal density structure, interpreted primarily from gravity, were digitized from the location map and are shown in

Figure 5, along with two of the major tectonic features of the area digitized from the same location map, the Main Zagros Thrust (MZT) and the Zagros deformation front. The MZT was used by Snyder and Barazangi for the origin or zero "distance" location on the three profiles.

We digitized the major crustal interfaces of the three profiles and converted them to km, with distance measured positive NE from the MZT and depth negative below sea level. The profiles are shown together on Figure 6, with a vertical exaggeration to make the crustal features more visible. Note that the major change in Moho depth is the crustal root of the high elevation part of the Zagros, in the region of the MZT, which reaches down past 60 km depth. Much of the rest of Iran, the Arabian/Persian Gulf, and northeast margin of the Arabian plate has Moho depths close to 40 km depth.

A Bouguer gravity grid has been built for the Zagros Mountains in Iran, Iraq and nearby regions, from a point data set. In addition, a contour map was generated from this grid. Free air gravity values are also available for the area and the same procedure is in process to obtain both the grid and the contours.

3.2.3. Israel

Deep seismic refraction data were collected along six profiles in Israel and occupied territories in 1977 and first described by Ginzburg and others (1979a, b). Large shots in the Dead Sea, Mediterranean, and Gulf of Aqaba provided strong sources. The detailed interpretation of the refraction profiles are described by Ginzburg and Folkman (1980) and Ginzburg and others (1981). In addition, four shorter refraction profiles were shot across central and northern Israel by the Israel National Oil Co., only one of which was long enough to provide data on the deep crust (Ginzburg and Folkman, 1980). The locations of the profiles were digitized and are shown on Figure 7. Also shown on Figure 7 are the locations of the shot points 1–8 used in the 1977 survey. Their naming scheme for refraction receiver lines used line 3 for the longest of the oil exploration profiles and lines I–VI for the 1977 profiles, but to avoid confusion on our figures between shot point numbers and line numbers, we have renamed the line 3 as line IIIa and the 1977 line III as line IIIb. The location of the major tectonic feature in the Israel/Jordan

area, the Dead Sea fault system, which forms the margins of the Dead Sea "rift" and marks the "leaky transform" plate boundary between the Arabian Plate to the east and the Mediterranean plate to the west has been digitized and plotted on Figure 7 for reference.

All of the interpreted 1D and 2D velocity structure figures of Ginzburg and Folkman (1980) and Ginzburg and others (1981) have been digitized. The crustal structure of northern and central Israel is shown on Figure 8 by interpretations of the two refraction lines (IIIa and IV) running from the Dead Sea to the Mediterranean (Ginzburg and Folkman, 1980). The structure of the northern Sinai and southern Israel from line VI is shown in Figure 9 (Ginzburg and others, 1981). The depth of the Moho between the Dead Sea and the Mediterranean decreases northward from more than 40 km in the Sinai to less than 25 km in northern Israel. The crustal thickness also decreases and sediment thickness increases towards the Dead Sea and Mediterranean. The one-dimensional velocity-depth function for line VI is shown in Figure 10.

The crustal structure of the Dead Sea "rift" from the Sea of Galilee to the Gulf of Aqaba is shown by the composite section of Figure 11 (from lines I, II, and IIIb) and the profiles of individual ray tracing models (Ginzburg and others, 1981). The large shots at shot point 4 in the Dead Sea provided good records out to long distances. The amplitude variations of secondary arrivals indicate the presence of a 5 km thick transition zone at the base of the crust with a gradation in P velocity from 6.72 to 7.9 km/s, and this zone is interpreted to extend along the entire composite section of the "rift". The depth to the Moho varies slowly from a maximum of about 35 km near Elat to about 27 km on the western margin of the southern Gulf of Aqaba and about 30 km in the north. A one-dimensional velocity-depth function is shown in Figure 12 for the Dead Sea shot point 4 along the "rift".

A contour map of Bouguer gravity of Israel has been digitized (Ginzburg and others, 1993) and a grid has been built from it. This grid has been merged with the grids for Lebanon and Syria (Khair and others, 1993; Best and others, 1990) (Figure 13). To be able to append these adjacent grids, the contours have been smoothed and joined through the country borders.

3.2.4. Jordan

A set of four refraction lines were collected in Jordan in May 1984 by the University of Jordan, Amman with the Institutes of Geophysics of Hamburg and Karlsruhe Universities (El Isa and others, 1987). We have digitized the line and shot-point locations, shown as Figure 14. Also shown on Figure 14 is the location of the Dead Sea fault system. The best long-range refraction results were obtained using large shots at shot-points 1 to 5, with recordings out to 200 km distances at a station spacing of 5 km along lines I to IV. A more detailed short-range dataset was collected along line II with smaller shots at shot-points 6 to 10 with stations out to 30 km distance and a station spacing of 1 to 2 km.

One-, two-, and three-dimensional velocity structures were interpreted and published by El Isa and others (1987), and we have digitized the one- and two-dimensional figures (due to perspective distortion it is not possible to digitize the three-dimensional figure). The one-dimensional velocity-depth functions beneath central Jordan are shown in Figure 15, derived from quarry explosion at shot point 3 and recorded along line II. Model 1 corresponds to the two-dimensional model of Figure 16 and Model 2 corresponds to a reflectivity synthetic seismogram interpretation of the same data. The two-dimensional velocity-depth-distance profiles are shown in Figures 16-18. The depth to Moho is between 30 and 40 km for all of Jordan, shallower to the west (closer to the Dead Sea rift) and deeper to the east. Depth to crystalline basement increases towards the northeast from zero at the Precambrian (Proterozoic) surface outcrops in the southwest corner of Jordan to about 5 km in central Jordan.

3.2.5. Saudi Arabia

Two deep refraction surveys have been shot in Saudi Arabia, one very long profile was collected across southern Saudi Arabia, and several shorter profiles were collected in NW Saudi Arabia in collaboration with German researchers. The ~1000 km long refraction line from the Farasan Islands in the Red Sea across to the other side of the Arabian Shield in central Saudi Arabia was conducted mostly by the USGS in 1978 (Blank and others, 1979; Healy and others, 1982; Mooney and others, 1985). The locations of the receiver arrays were digitized from the 1:2,000,000 scale map of Plate 7 of Healy and others (1982) and are shown on

Figure 19, along with the digitized locations of the seven shot points (two shot points were located close together and are both adjacent to the label 6 on the figure).

An IASPEI workshop was held in 1980 to compare a wide variety of different interpretations of the 1978 refraction profile data and the results were published in a proceedings volume (Mooney and Prodehl, 1984). The interpretations were quite similar in the relatively simple Arabian shield area, but varied widely in the transition into the Red Sea rift where the velocity structure changes rapidly. We chose to start with the interpretation of the USGS group for our database. The large 1:2,000,0000-scale interpreted section in Plate 9 of Healy and others (1982), which is similar to that of Mooney and others (1985), was digitized, converted to distance-depth coordinates in km, and plotted in Figure 20.

The next step was to convert the distance-depth coordinates of the interpreted section (Figure 20; Healy and others, 1982) to geographic coordinates that can be plotted on a map. We selected the interpreted Moho interface from the database, converted the vertices along the Moho to points, and then projected the points onto a strike-line running along the length of the refraction survey to obtain latitude-longitude-depth triplets for points of the Moho. The strike-line and Moho points are shown on Figure 19, with the depth of the points in km below sea level marked next to the point locations. In this interpretation from Healy and others (1982), the steepest slope of the Moho from about 38 km to 18 km depth occurs beneath shot point 5, some 50 km inland of the present Red Sea coastline, near the position of the topographic scarp, the Hijaz-Asir escarpment, that marks the edge of the rift zone and the beginning of the sediments of the coastal plain. On the Arabian shield, where Precambrian basement is exposed, the Moho is close to 40 km deep and the P velocities start over 6 km/s at the surface. At the NNE end of the profile, a thin layer of Phanerozoic sediments cover the basement surface that gently slopes eastward under the Arabian platform.

3.2.6. Syria

No deep refraction data have been collected in Syria, but several DSS lines with detailed information on the upper and middle crust were shot. These profiles

have been reinterpreted at Cornell (using the original analog seismic recordings) and provide excellent information on the thickness of the sedimentary basins and depth to basement in Syria (Seber and others, 1993). An ongoing Cornell collaboration with the Syrian Petroleum Company has brought to Cornell many other datasets for Syria, including seismic reflection lines, drill hole, and gravity data. Maps and cross sections showing the results will be presented in future releases.

The gravity data have already been digitized and gridded with 1000 meters cell size (Figure 13).

3.2.7. Lebanon

The contours from a Bouguer gravity map of Lebanon (Khair and others, 1993) have been digitized. From this Arc/Info coverage a grid has been built by using topogrid with 1000 meters cell size. The contours were appropriately joined to that from Syria and Israel so the appended Syria-Lebanon-Israel grid does not show abrupt changes in the country borders (see Figure 13).

3.2.8. Basement Map of the Middle East

We have digitized a preliminary map of the thickness of sedimentary cover for most of the Middle East (Figure 21). This map was prepared by Beydoun (1989) and shows the major variations in sedimentary thickness for the area. The western part of the Arabian plate, the Arabian shield, has Precambrian basement exposed at the surface, and the basement slopes eastward under sediments up to 45,000 ft (~14 km) thick in the Zagros. To the west of the Arabian shield, a steep scarp forms the edge of the Red Sea rift zone with up to 15,000 ft (~4.5 km) of sediments. This map should only be used to get an overall view of the sediment thicknesses. We converted the depths to metric units and generated a grid from these contours (Figure 21). Figure 22 shows an example of a cross section across the Arabian plate showing surface topography and seismic basement. The very thick sedimentary cover in the Mesopotamian foredeep could significantly affect

the propagation characteristics of high- frequency crustal seismic phases, such as Pg and Lg.

We will improve and expand this database with more accurate and extensive information in our next release.

3.3. North Africa

An extensive point dataset of Bouguer and free air gravity values from the Bureau Gravimetrique International (BGI), allowed the generation of a gravity grid of North Africa. The density of the spatial distribution of the data varies considerably for different areas. The best represented countries are Morocco and Egypt. These grids have been generated with 1000 meters cell size for small areas and then merged together by using the Arc/Info Grid function, mosaic. It uses a weighted average method on the overlapping areas giving smooth transition. More work is still required before we make this database available via the network. Moreover, we expect to include considerably more geophysical and geological databases for North Africa in a future release.

3.4. Chart of the World

The Digital Chart of the world is a 1:1,000,000 scale basemap of the world published by the USGS. This database is originally divided in 5° by 5° tiles. The tiles have been appended together as well as their arc, point, and polygon attribute tables in a region covering the Middle East and North Africa. These descriptive attributes are codes in the individual tiles (i.e., popytype = 1 indicates land, and popytype = 2 indicates oceans). However, after appending the tiles, new character-type items were added, describing the code numbers for each attribute table. The following layers are available: "Drainage", "Physiography", "Political and Oceans", "Populated place", "Roads, Railroads and Transport Structure" and "Utility".

4. ACCESS TO DATABASES

We are releasing these databases in several different forms, all accessible over the Internet. We are now using the well-established anonymous FTP protocol, but we are also using the World-Wide Web (WWW) protocols that are rapidly increasing in popularity on the Internet due to their more sophisticated functions and the excellent Mosaic client program available from the National Center for Supercomputing Applications (NCSA). In particular, the Mosaic client and Gopher servers can be used to create custom figures on a remote system that can be viewed on a local workstation. Mosaic versions now run on most X workstations, Macintoshes and PC-compatibles under Windows. Our Web address is "http://www.geo.cornell.edu/geology/me_na/main.html".

Our anonymous FTP server is hugo.geo.cornell.edu and the data are stored in the pub/arpa directory and subdirectories. There is a new subdirectory pub/arpa/mideast with further subdirectories below that for each country described above. We are releasing the data in several different forms on the FTP server, the finished figures of this report in PostScript and Adobe Illustrator form, and the raw data in flat ASCII files as extracted from Arc/Info. The PostScript files (with the ".ps" suffix) can be printed on PostScript printers. The Adobe Illustrator files (with the ".ai" suffix) can be read by drawing and page layout programs that can handle Illustrator v. 3 format files, including the Adobe Illustrator v. 3.5 available for Sun workstations. The raw data files have several different formats for different types of information, and the file formats are explained in Appendix I (below) and in "README" files for each type available on the FTP server. Please address all questions, comments, and suggestions on the format and content of our network database to "seber@geology.cornell.edu".

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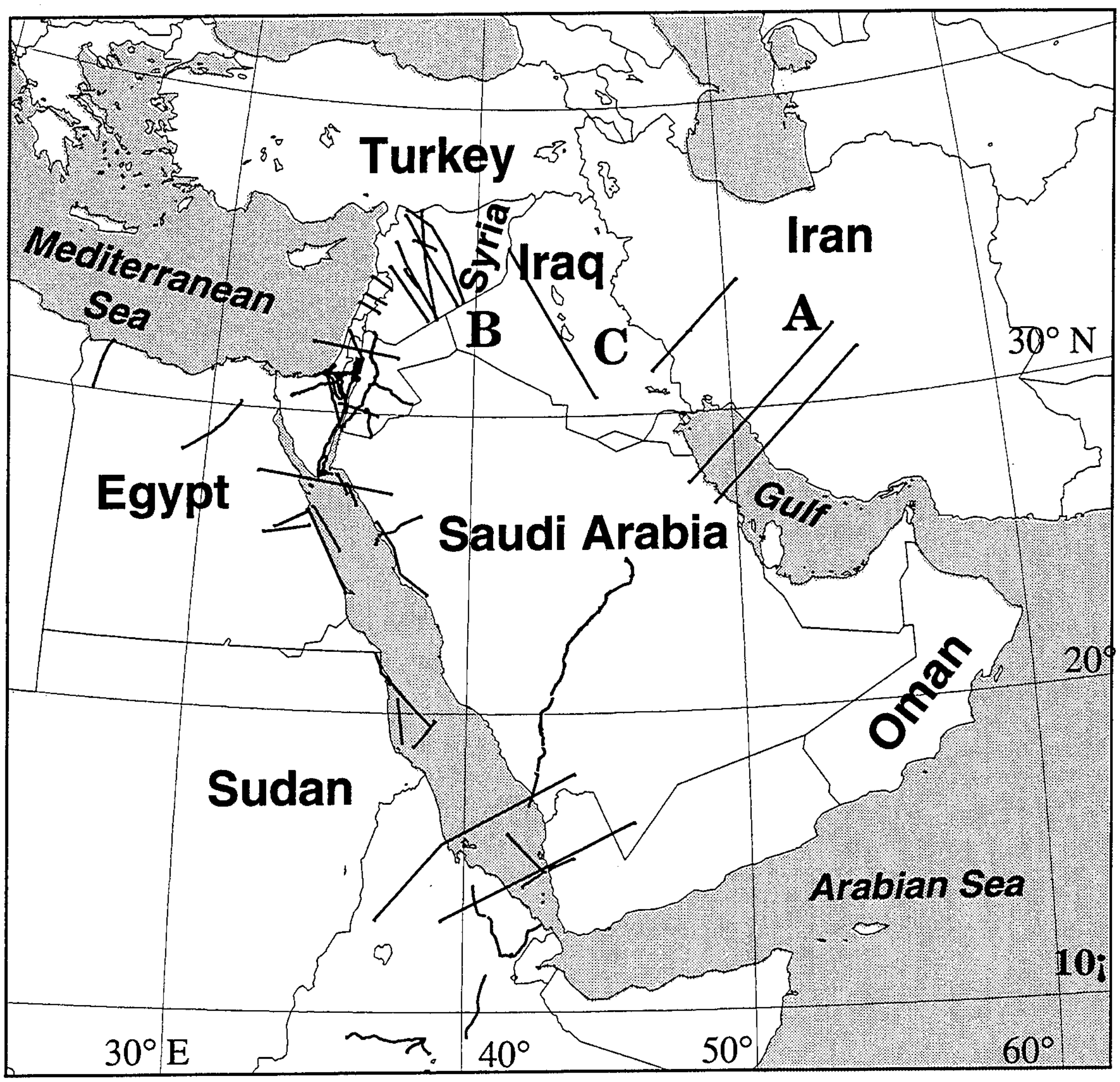
Middle East crustal profiles



Transverse Mercator projection

scale 1:25,000,000

Figure 1

Seismicity of the Middle East and North Africa (1960-1990)

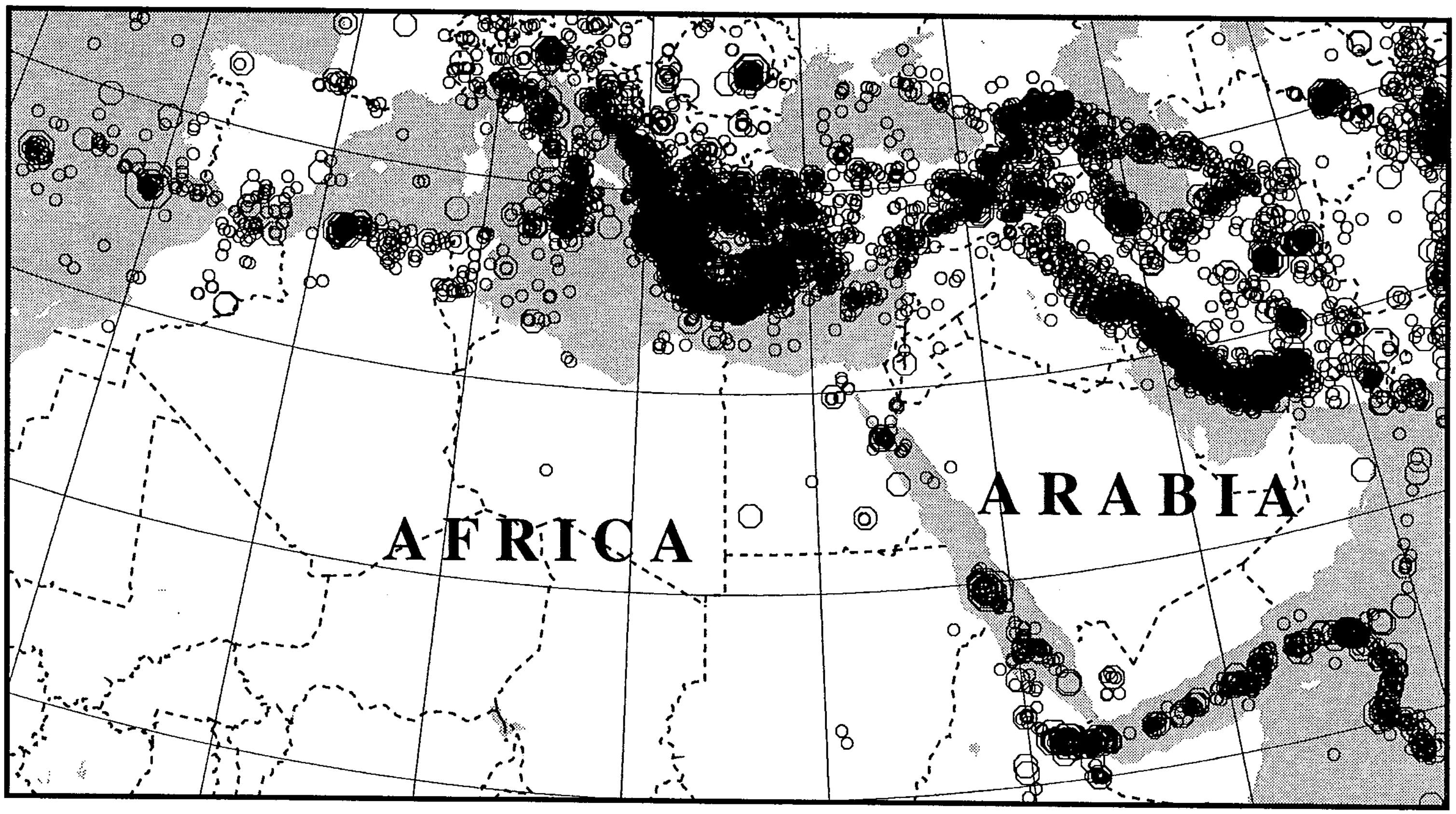


Figure 2(a)

Focal Mechanism Solutions of the Middle East and North Africa (1977-1992)

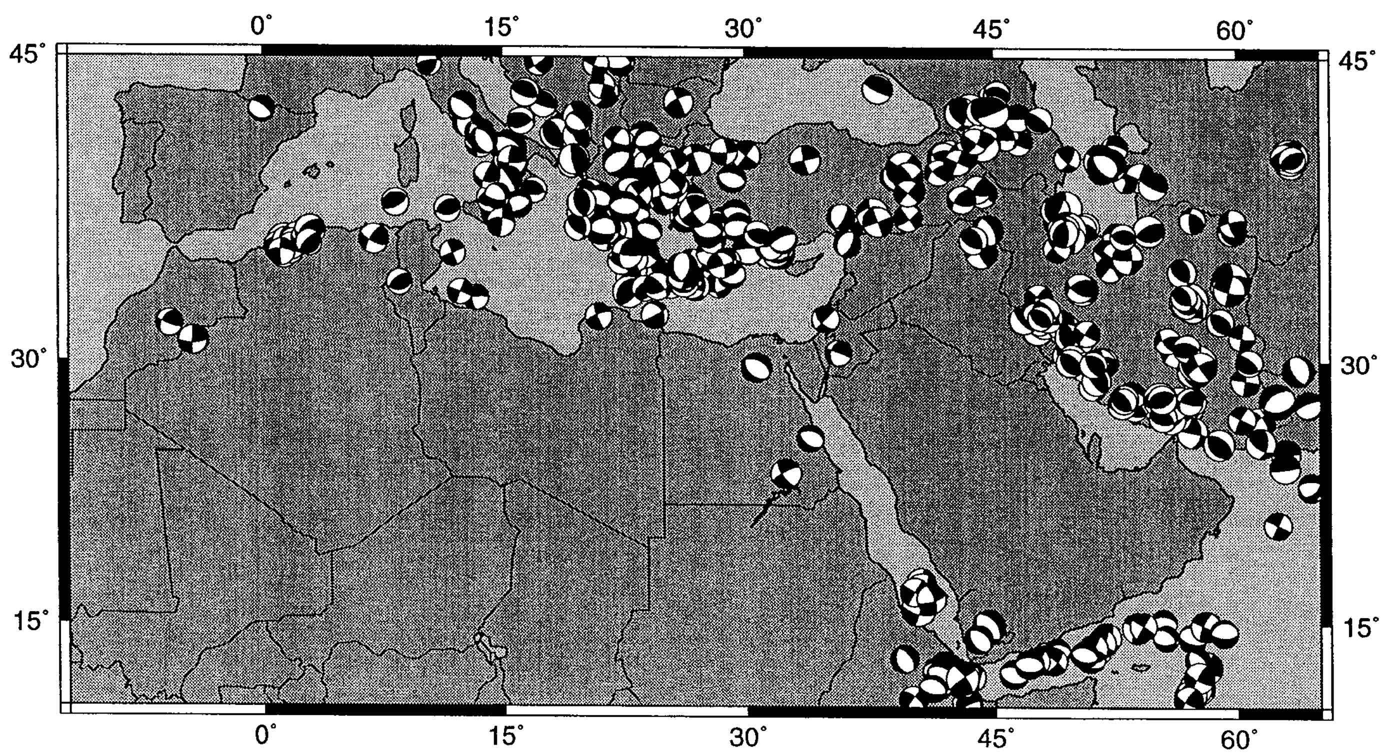


Figure 2(b)

Explosions in the Middle East and North Africa (1960-1990)

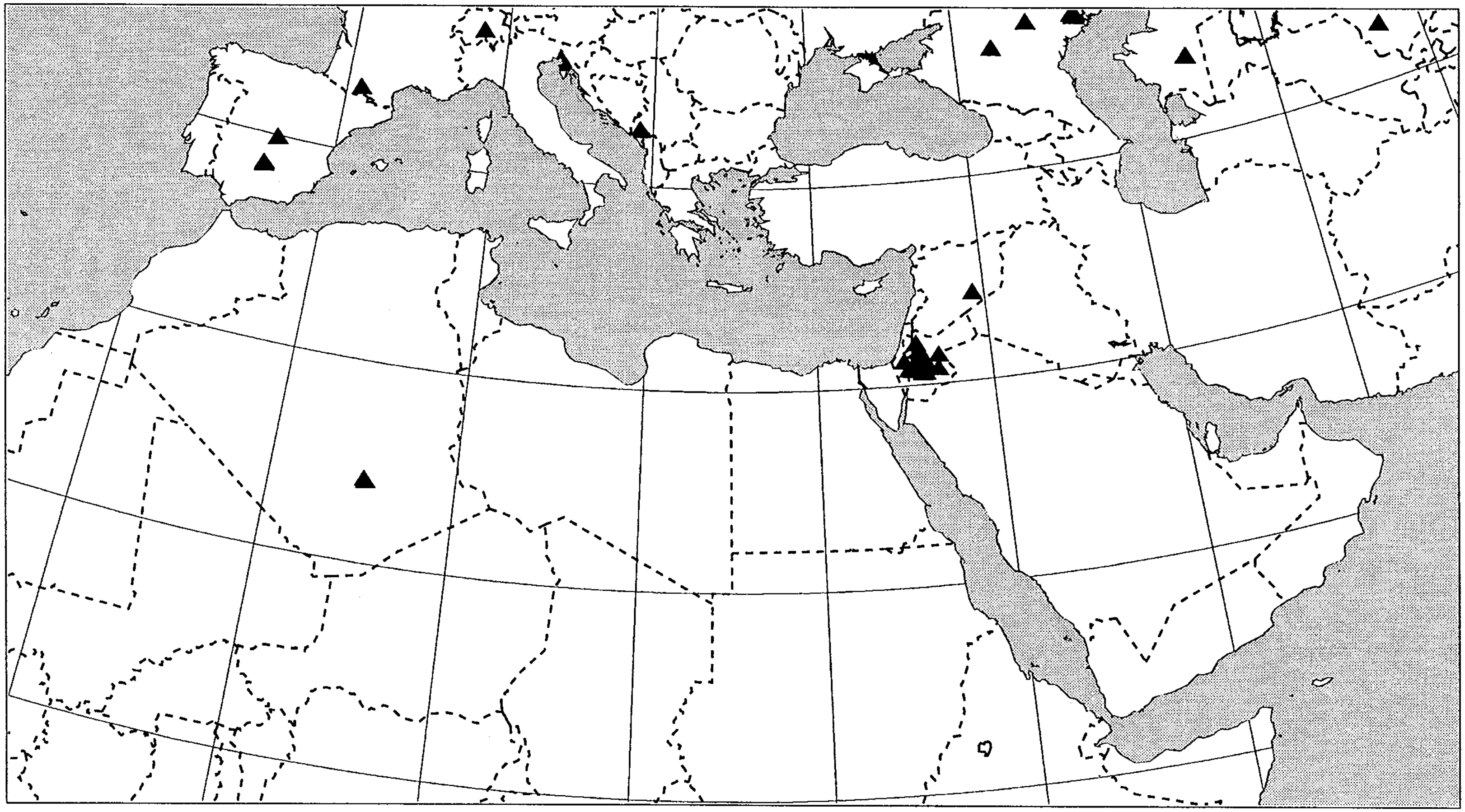
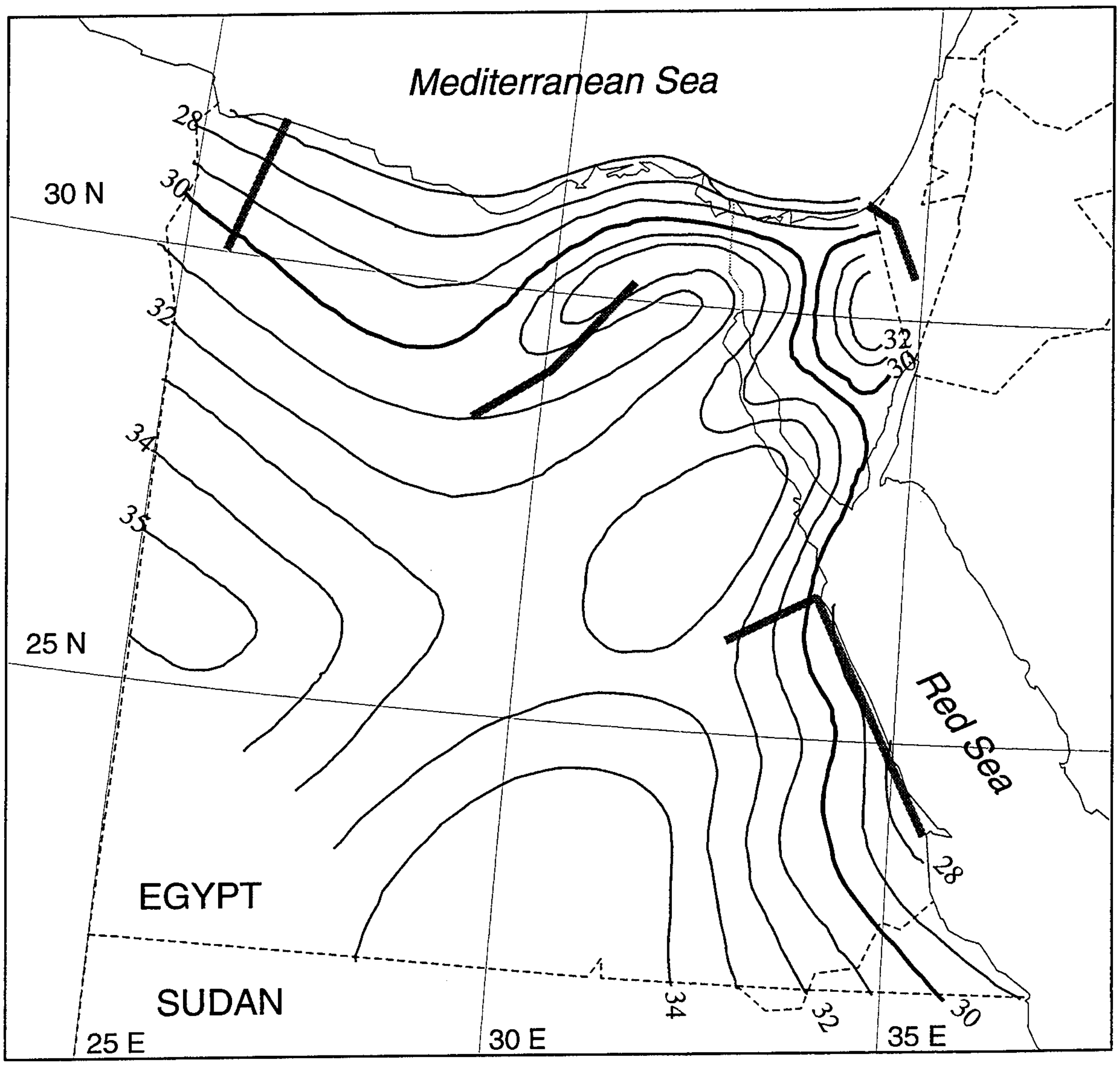


Figure 3

Egypt Moho depth



Transverse Mercator projection

Figure 4

Iran profiles

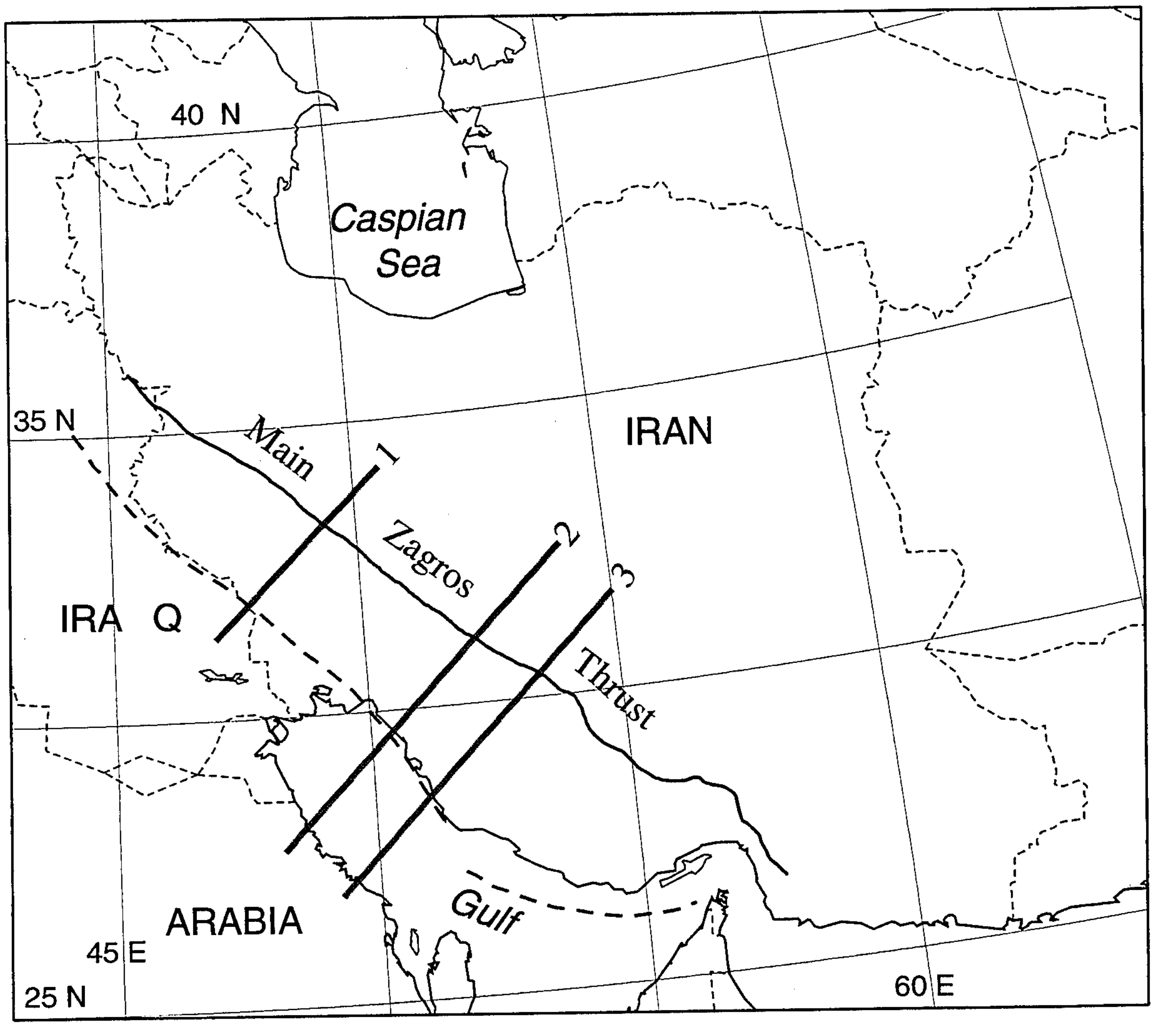


Figure 5

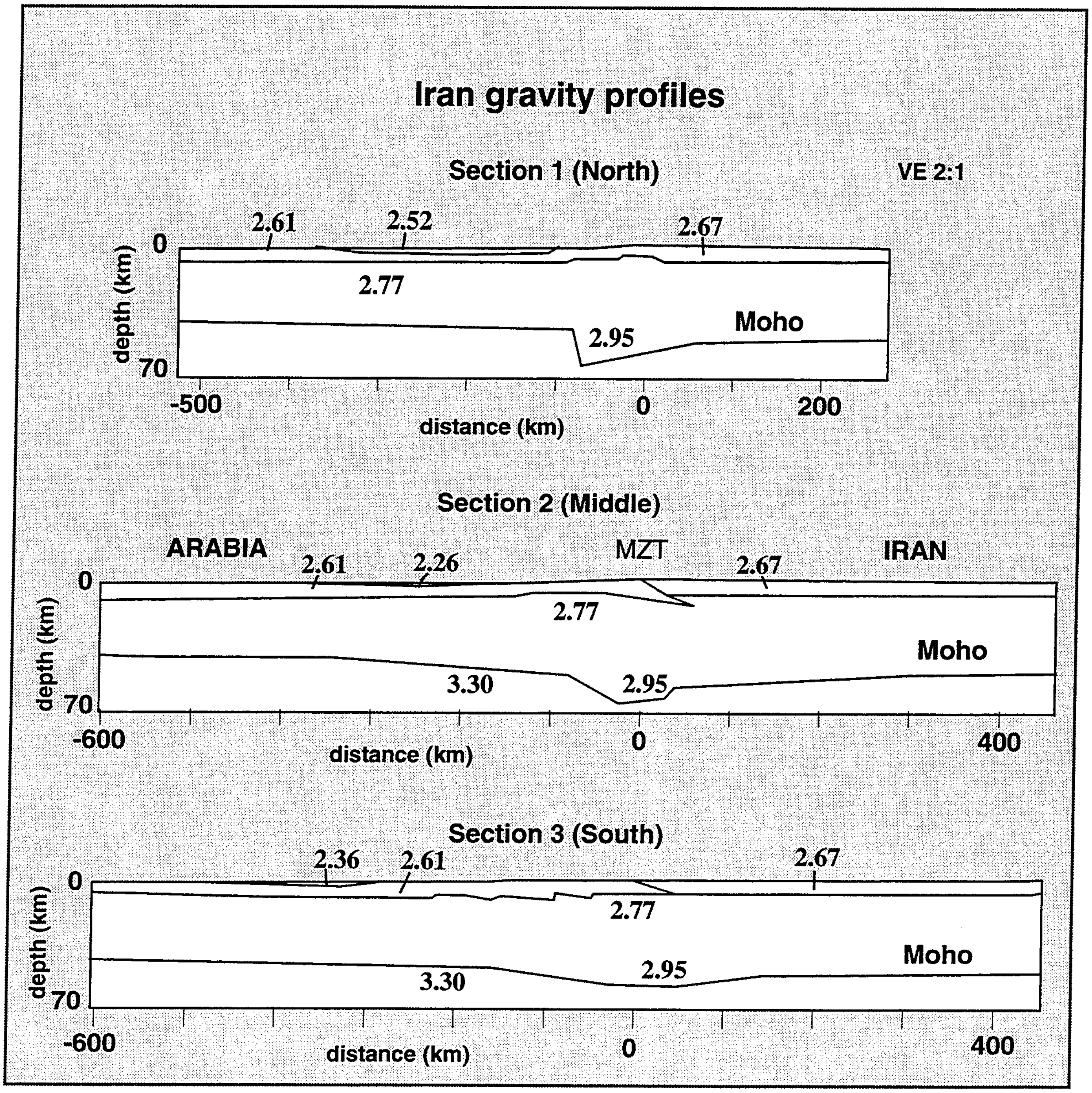
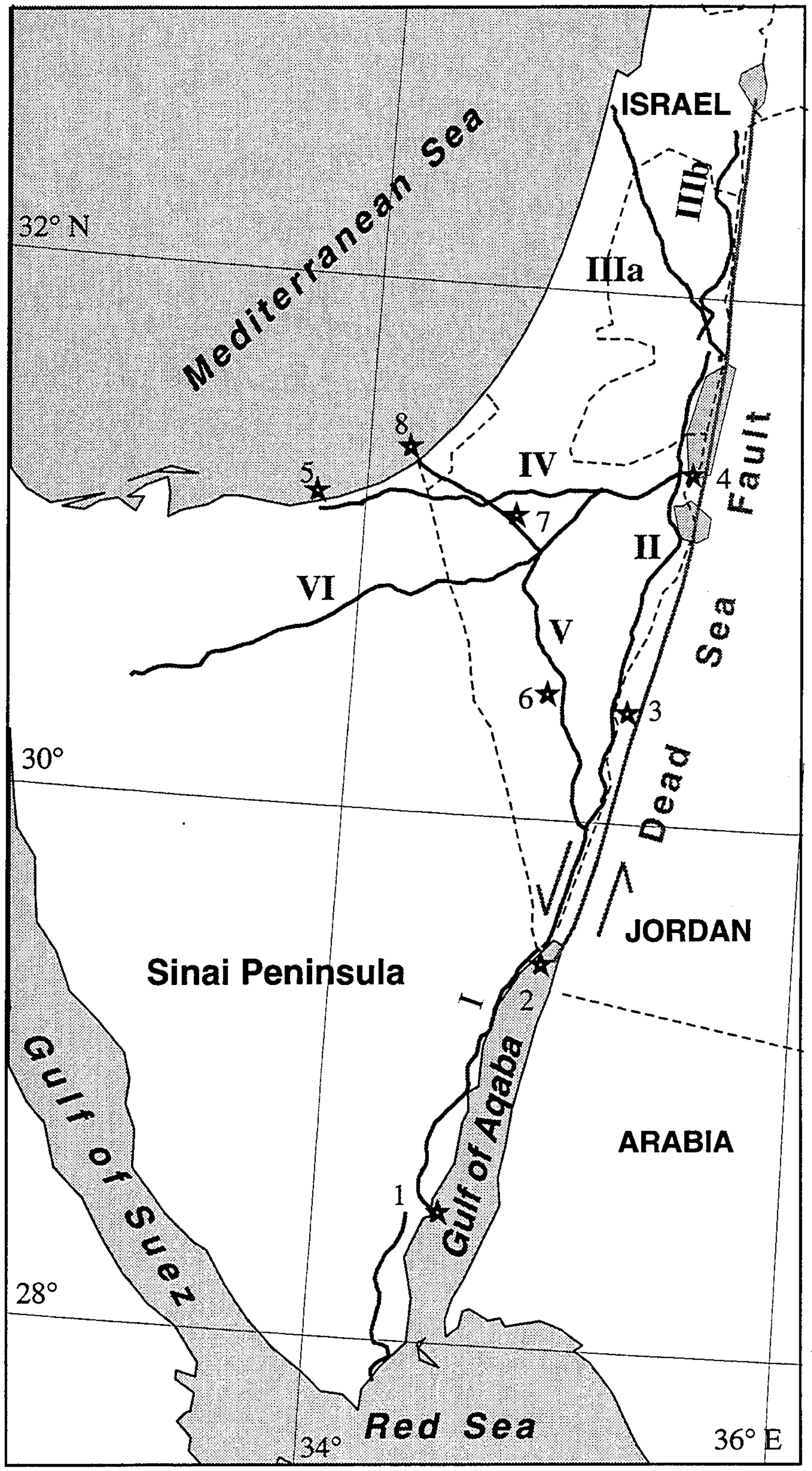
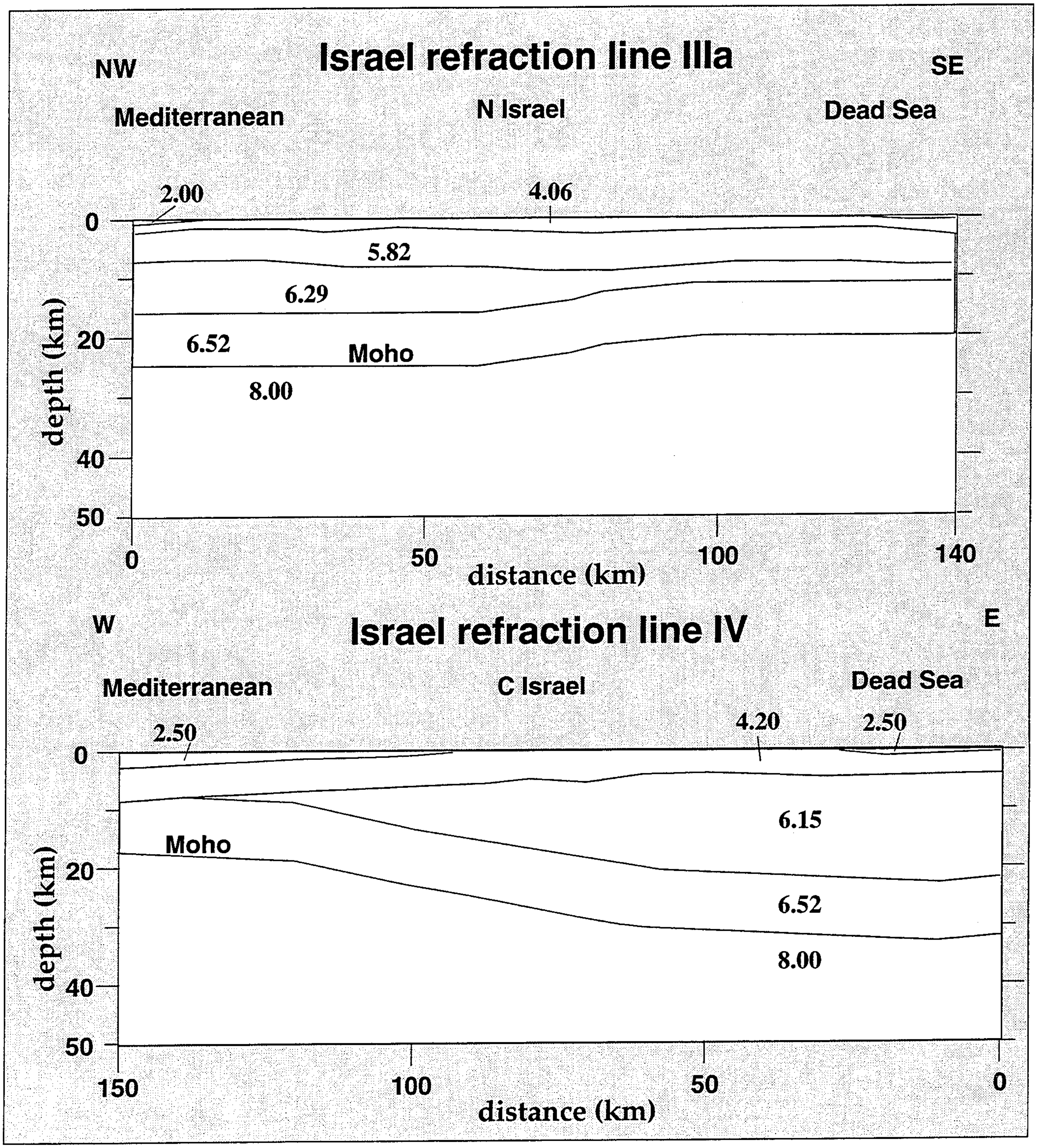

Iran gravity profiles
Section 1 (North)
VE 2:1
2.61
2.52
2.67
0
depth (km)
2.77
Moho
2.95
70
-500
0
200
distance (km)
Section 2 (Middle)
ARABIA
MZT
IRAN
2.61
2.26
2.67
0
2.77
depth (km)
Moho
3.30
2.95
70
-600
0
400
distance (km)
Section 3 (South)
2.36
2.61
2.67
0
2.77
depth (km)
Moho
2.95
3.30
70
-600
distance (km)
0
400

Figure 6



scale 1:3,000,000

Figure 7



Israel refraction line IIIa
NW
SE
Mediterranean
N Israel
Dead Sea
2.00
4.06
5.82
6.29
6.52
Moho
8.00
depth (km)
0
20
40
50
0
50
100
140
distance (km)
Israel refraction line IV
W
E
Mediterranean
C Israel
Dead Sea
2.50
4.20
2.50
6.15
Moho
6.52
8.00
depth (km)
0
20
40
50
150
100
50
0
distance (km)

Figure 8

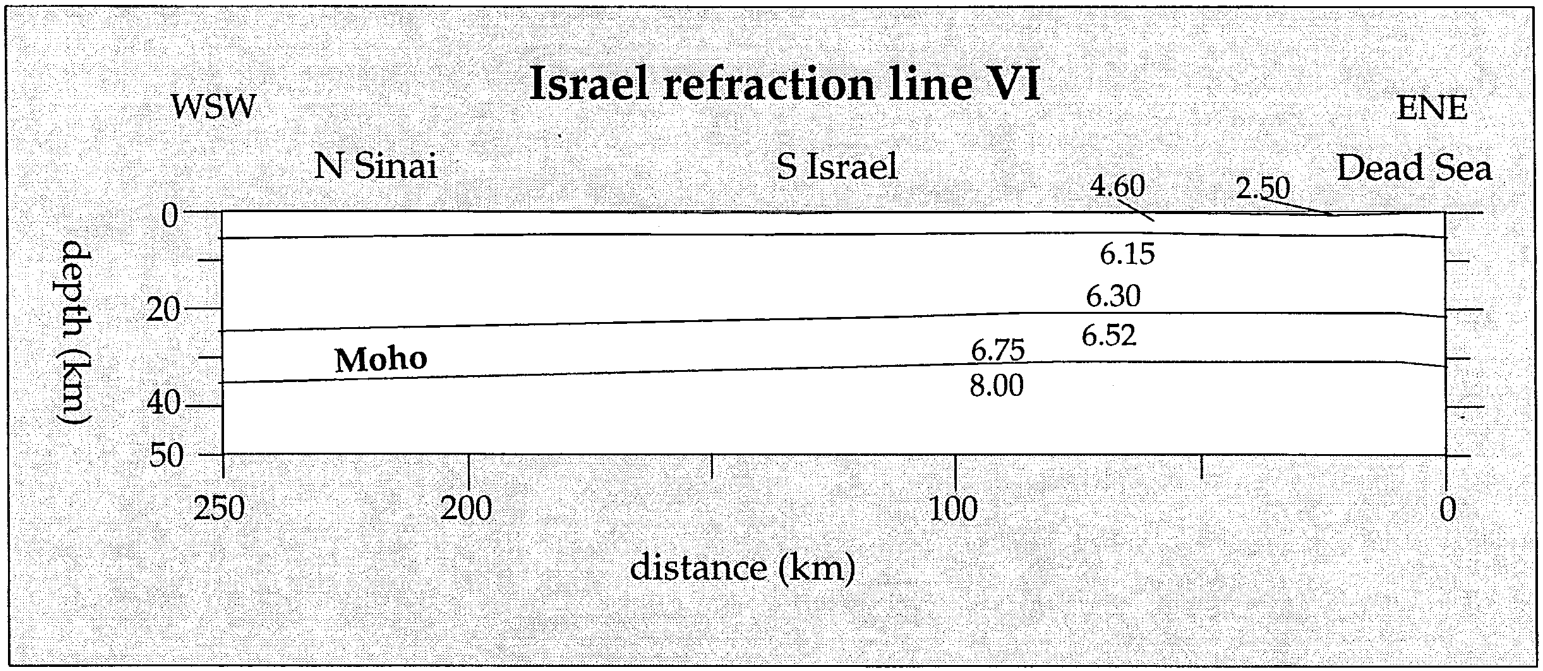
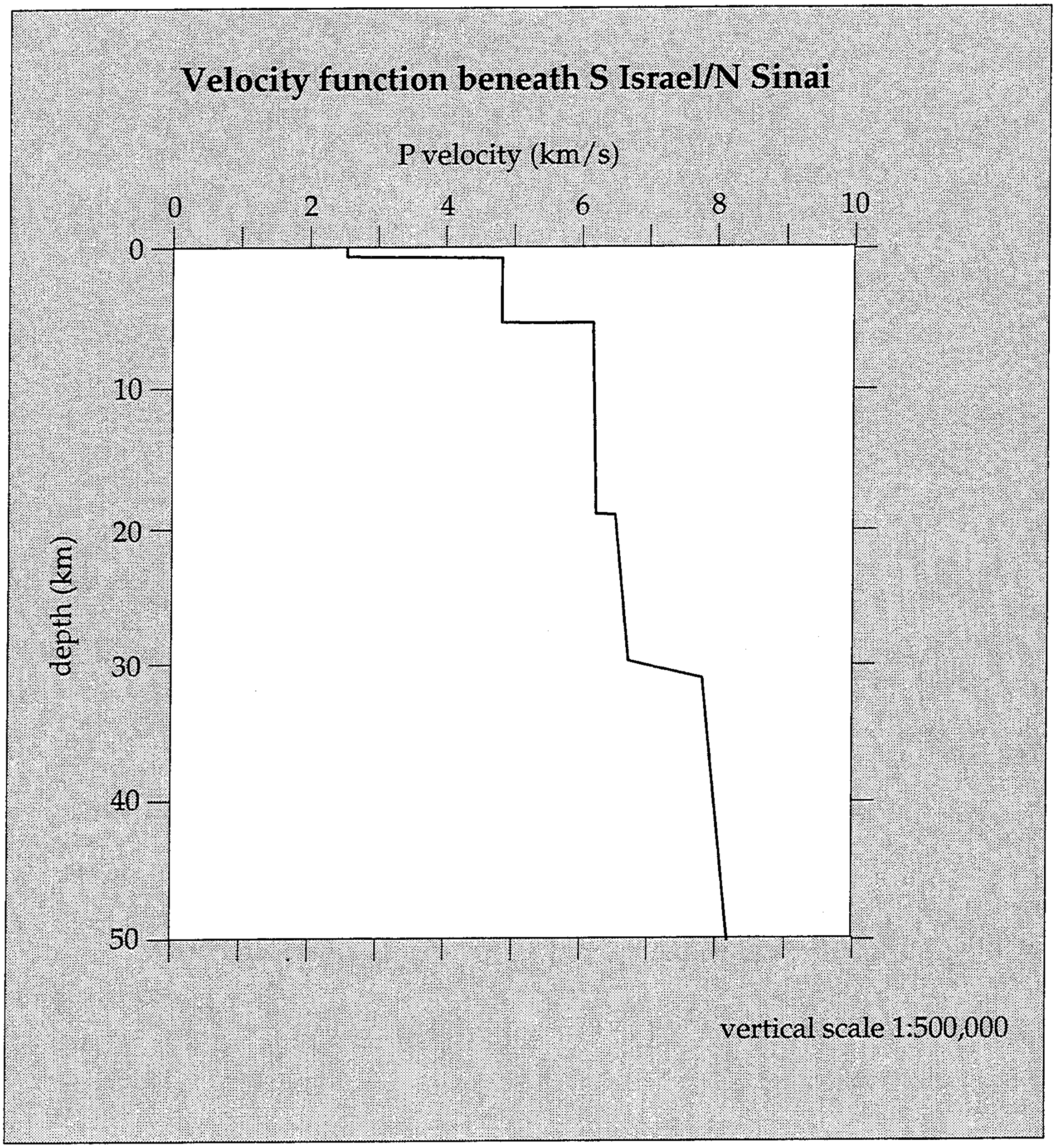
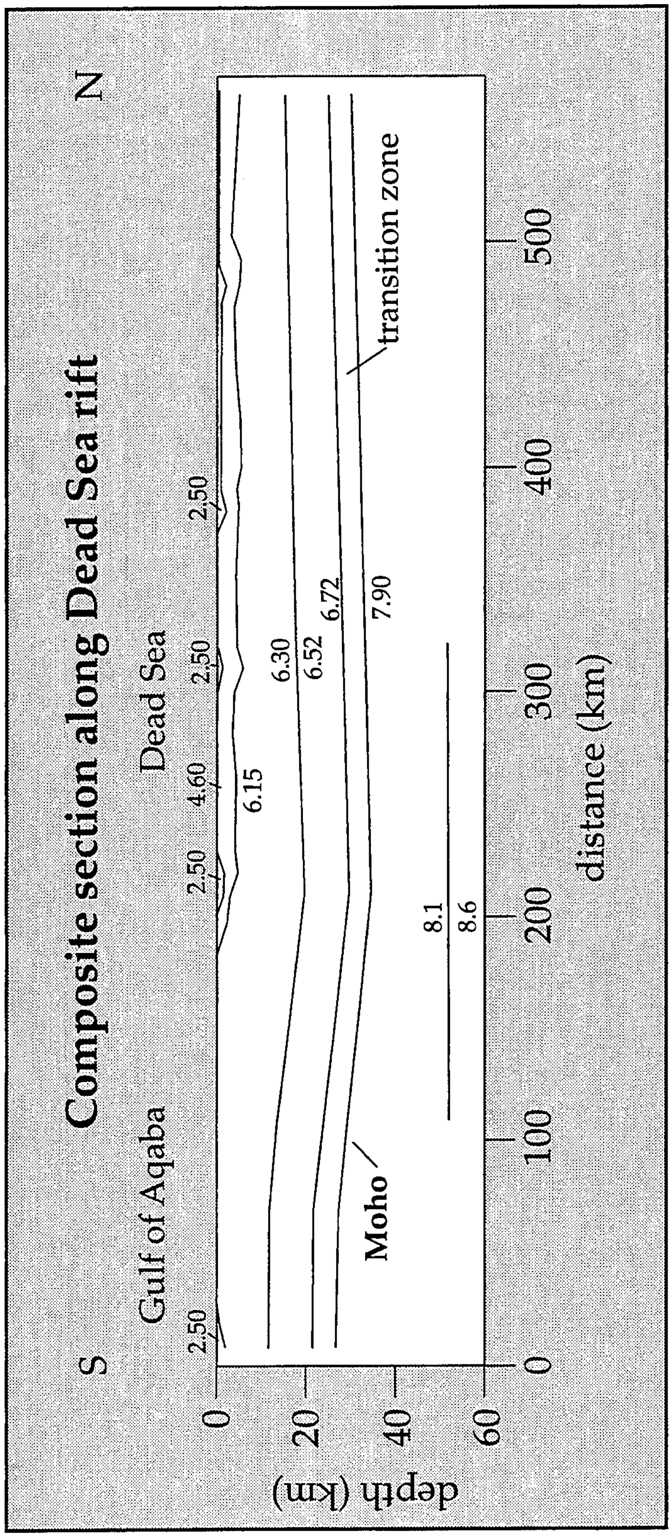

Israel refraction line VI
WSW
ENE
N Sinai
S Israel
Dead Sea
4.60
2.50
6.15
6.30
6.52
6.75
8.00
Moho
depth (km)
0
20
40
50
250
200
100
0
distance (km)

Figure 9



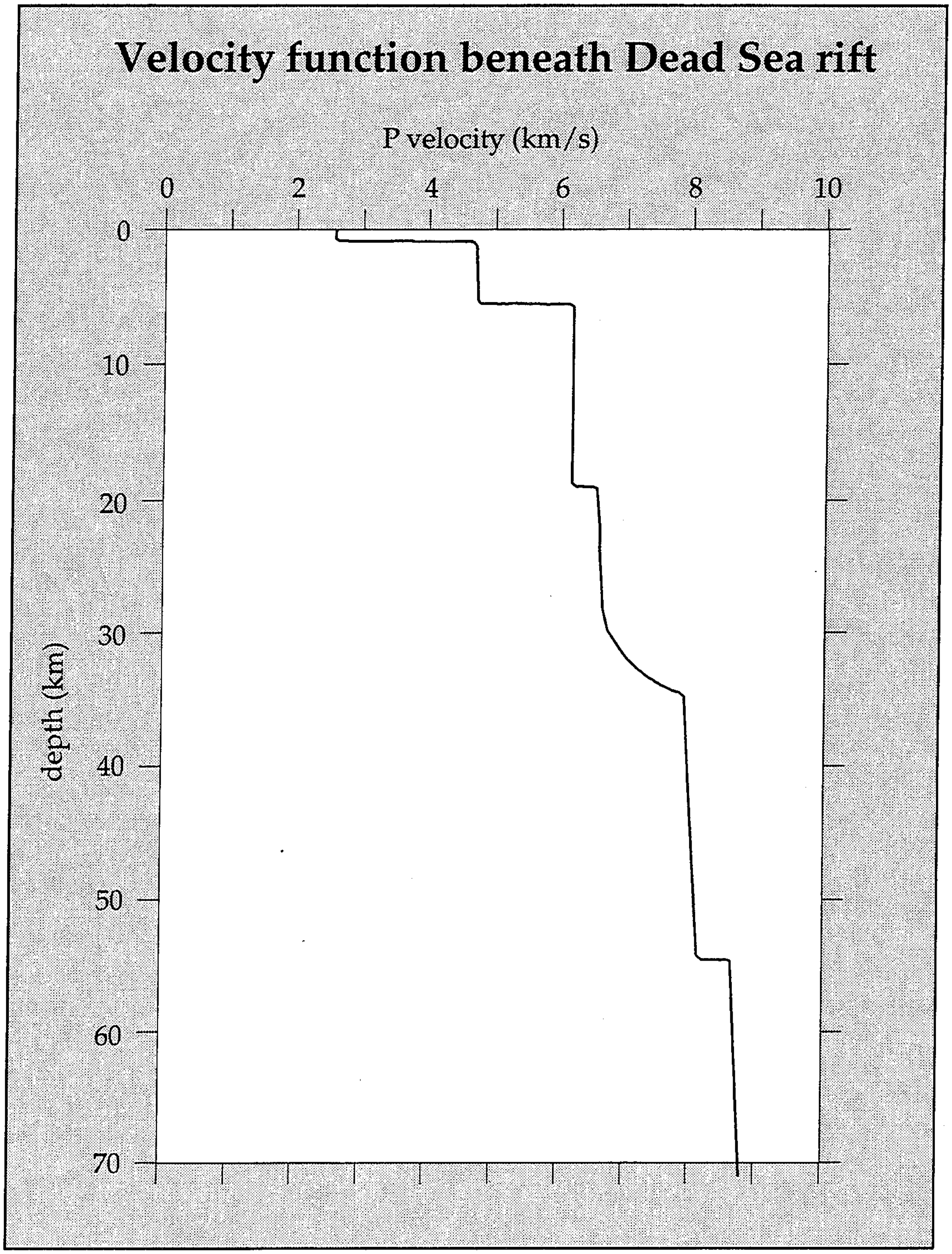
Velocity function beneath S Israel/N Sinai
P velocity (km/s)
0
2
4
6
8
10
0
10
20
30
40
50
depth (km)
vertical scale 1:500,000

Figure 10



Composite section along Dead Sea rift
S
N
Gulf of Aqaba
Dead Sea
2.50
2.50
4.60
2.50
2.50
6.15
6.30
6.52
6.72
7.90
8.1
8.6
Moho
transition zone
depth (km)
0
20
40
60
0
100
200
300
400
500
distance (km)

Figure 11



vertical scale 1:500,000

Figure 12

Bouguer Gravity Map of Syria, Lebanon and Israel

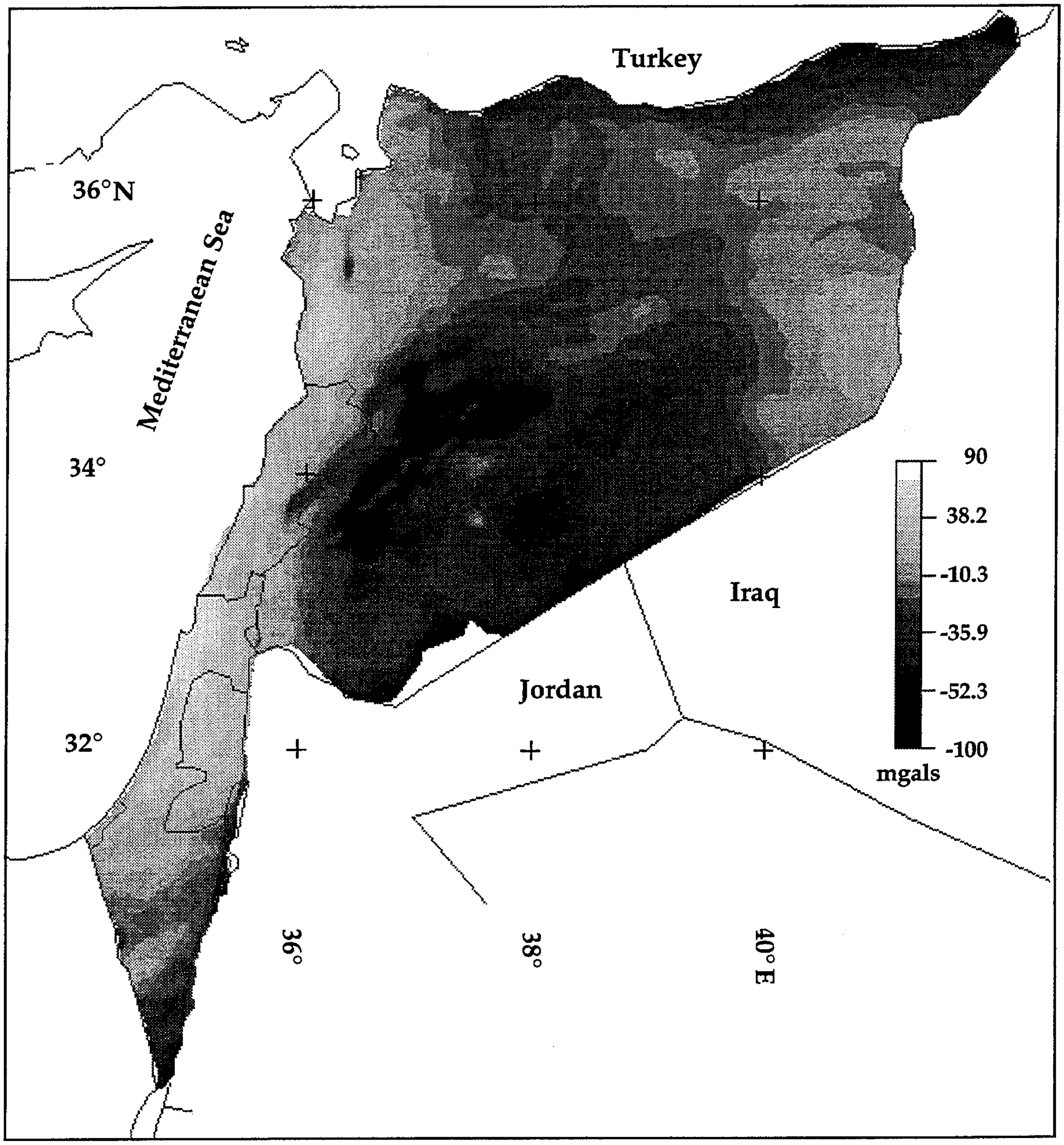


Figure 13

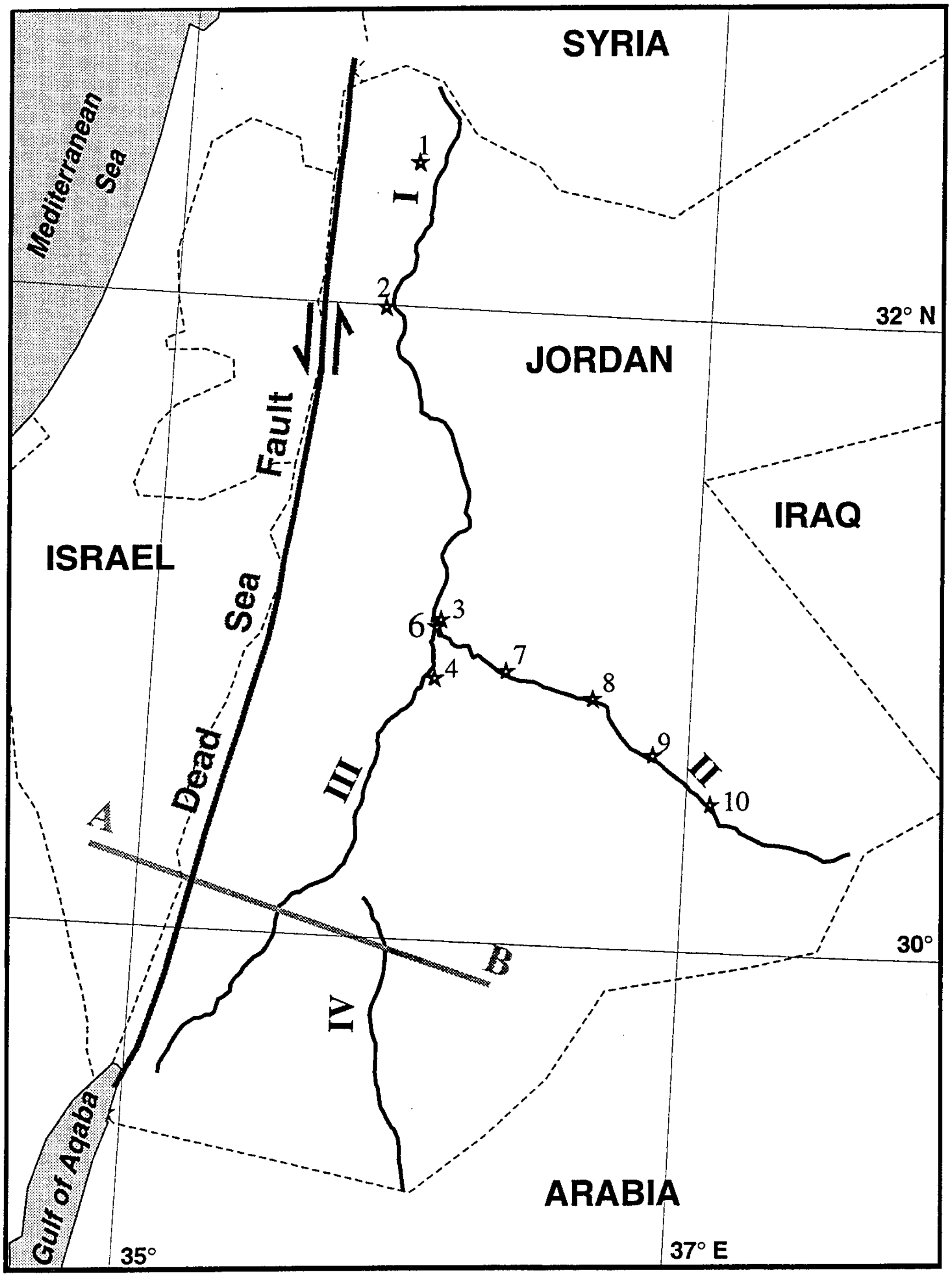
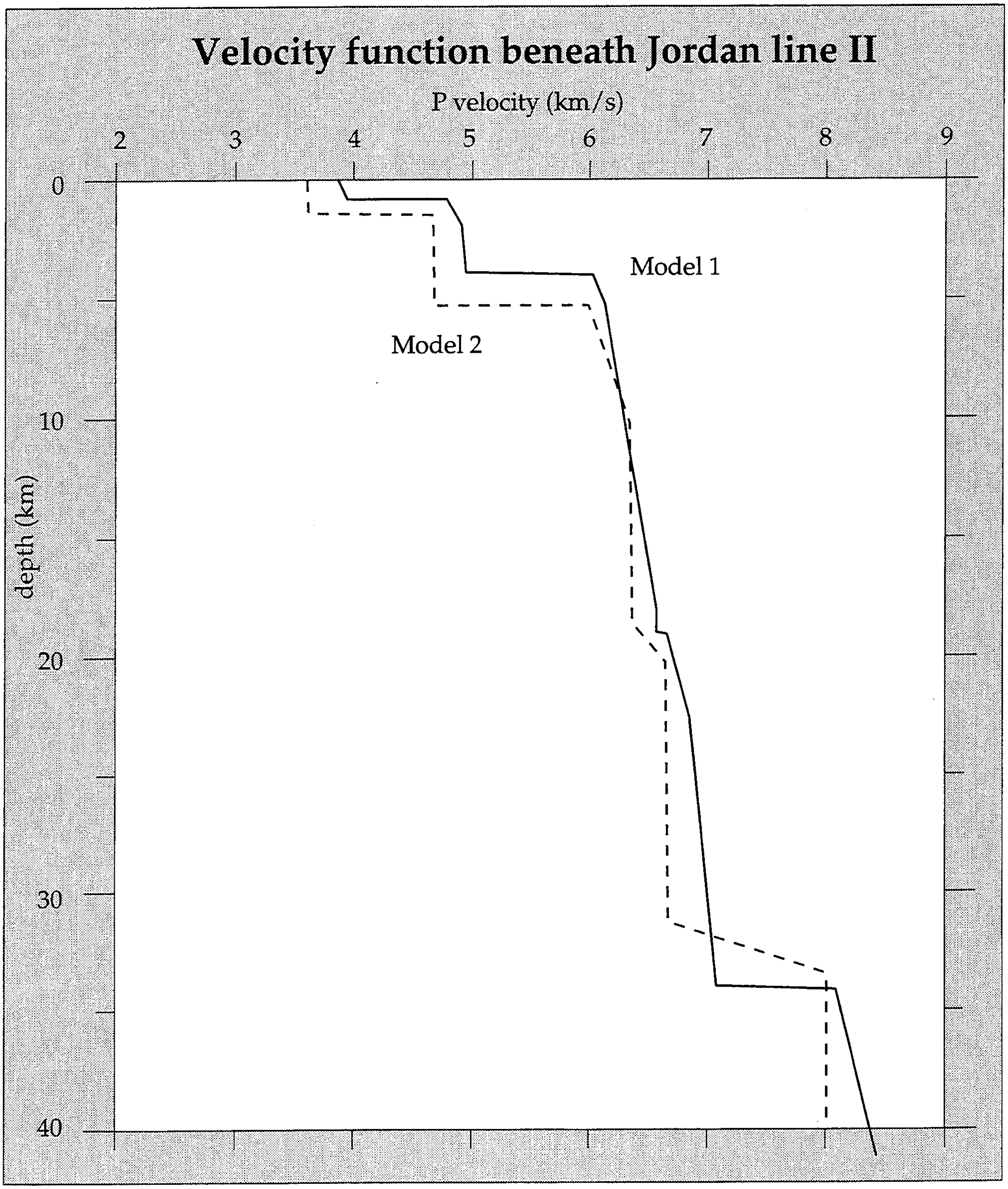
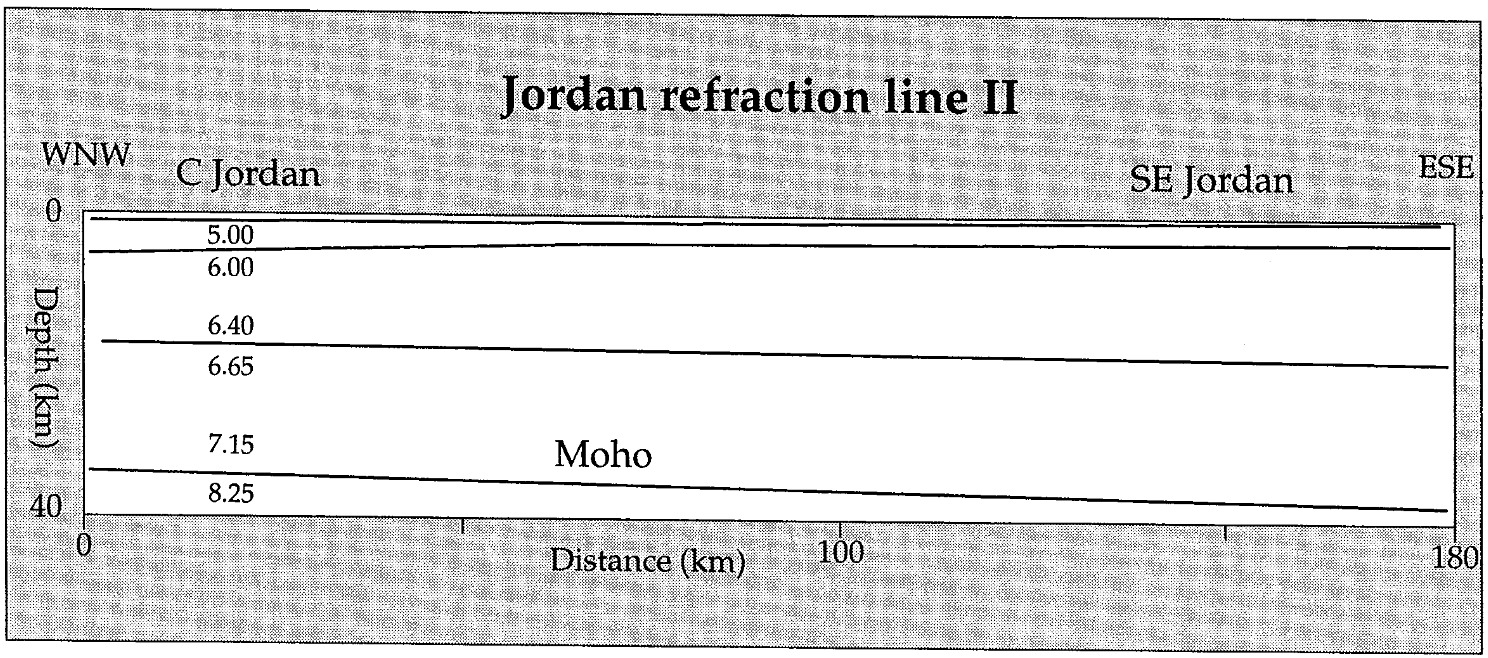

SYRIA
Mediterranean Sea
1
I
2
32° N
JORDAN
Dead Sea Fault
IRAQ
ISRAEL
6
3
7
4
8
9
II
10
III
A
B
30°
IV
Gulf of Aqaba
ARABIA
35°
37° E

Figure 14



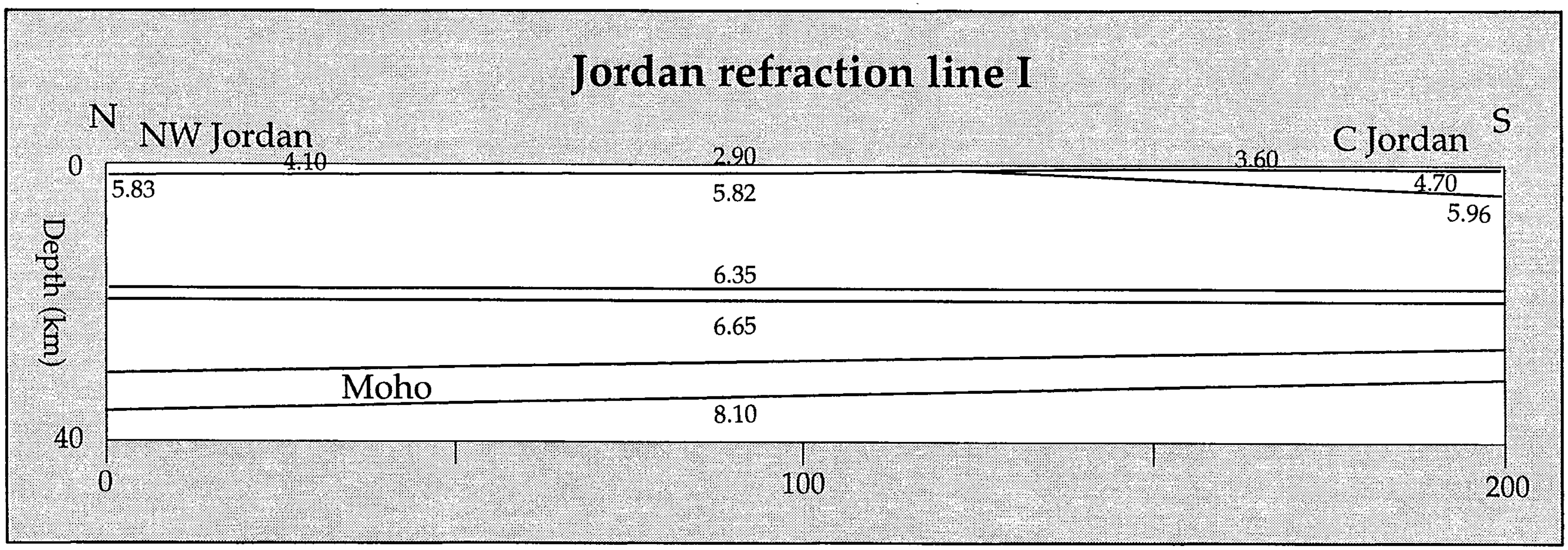
vertical scale 1:250,000

Figure 15



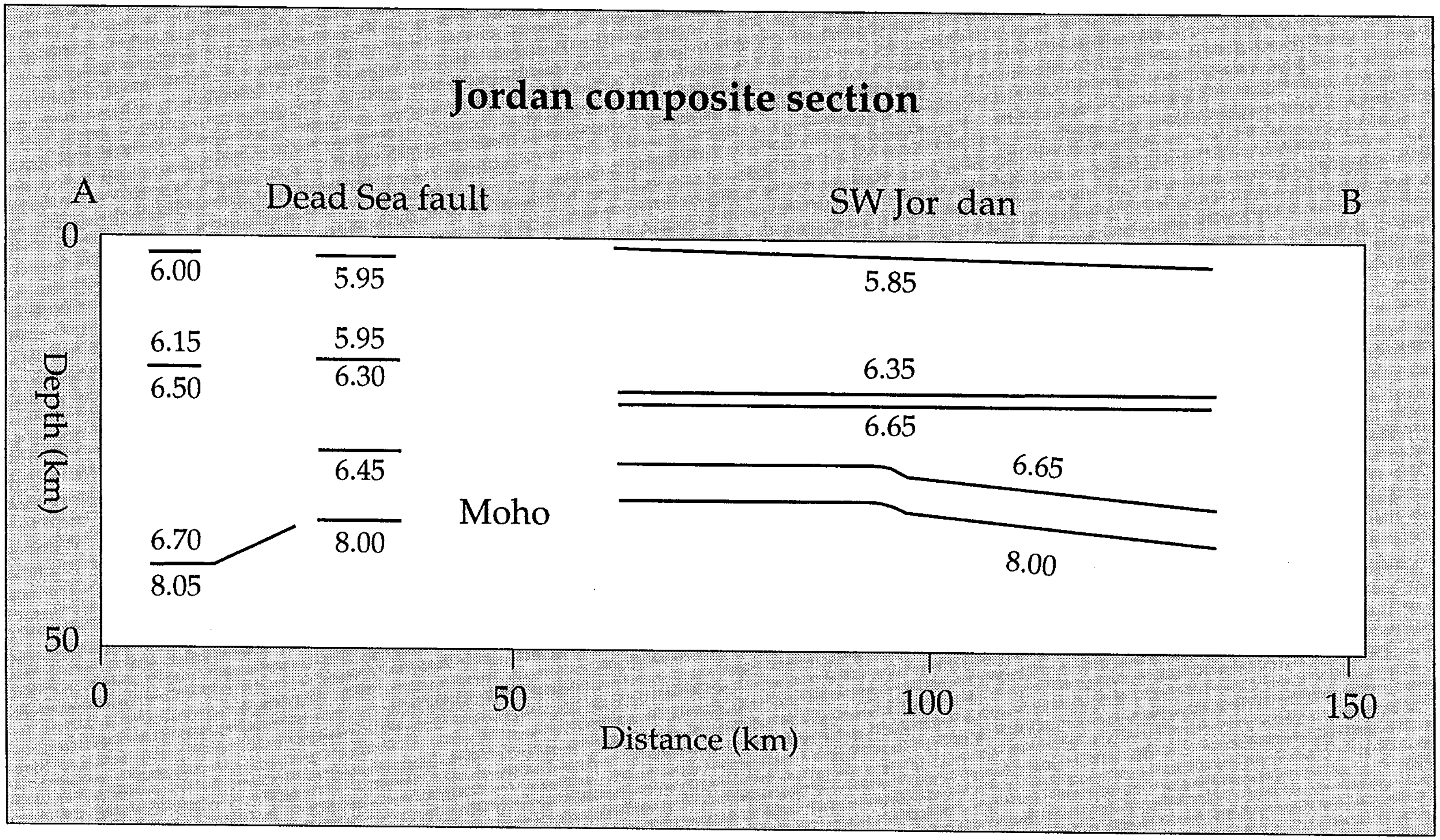
scale 1:1,000,000

Figure 16



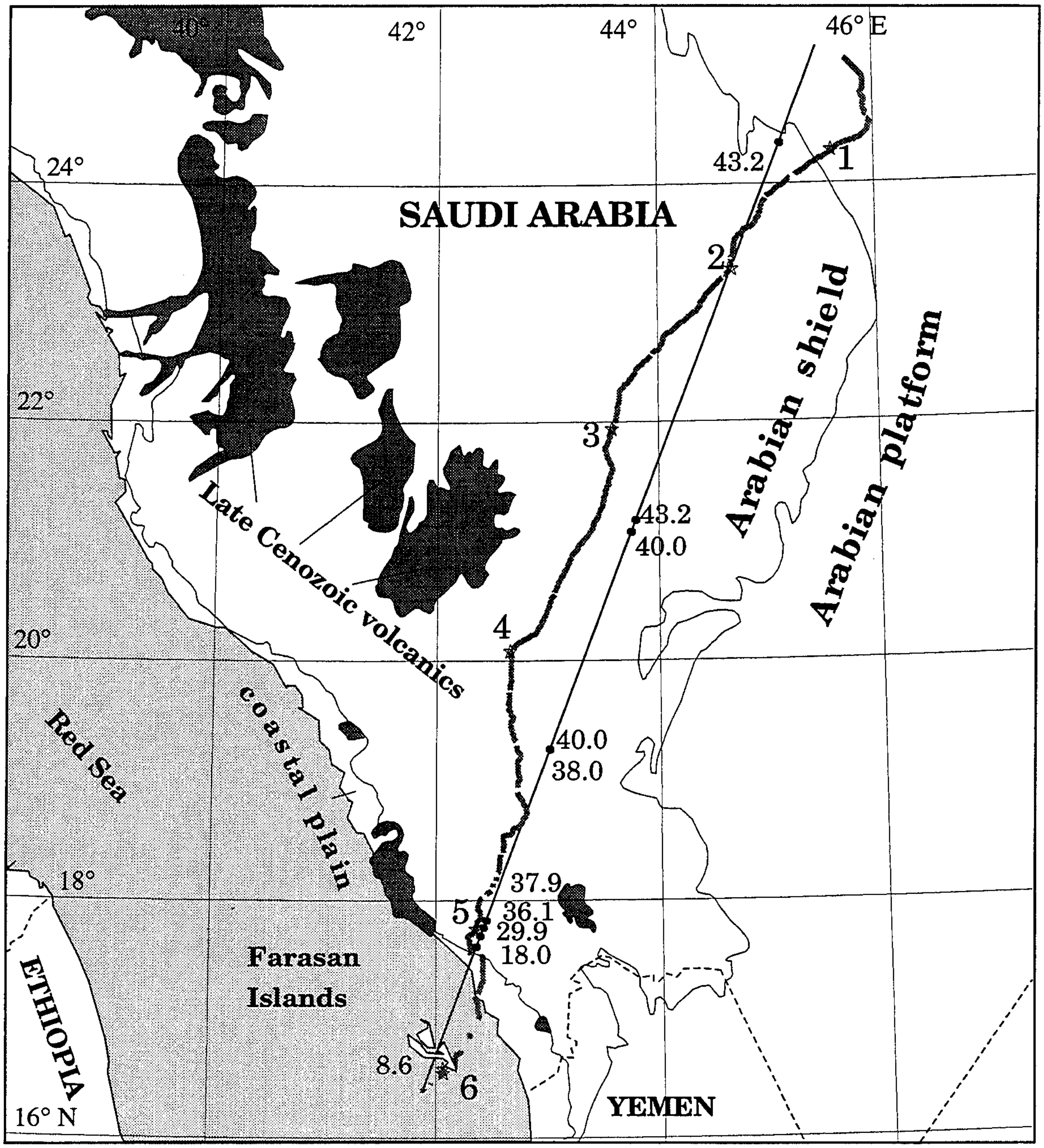
scale 1:1,000,000

Figure 17



Jordan composite section
A
Dead Sea fault
SW Jor dan
B
0
Depth (km)
50
6.00
5.95
5.85
6.15
6.50
5.95
6.30
6.35
6.65
6.45
Moho
6.65
6.70
8.05
8.00
8.00
0
50
100
150
Distance (km)

Figure 18



40°
42°
44°
46° E
24°
22°
20°
18°
16° N
SAUDI ARABIA
43.2
1
2
3
4
5
6
43.2
40.0
40.0
38.0
37.9
36.1
29.9
18.0
8.6
Arabian shield
Arabian platform
Late Cenozoic volcanics
coastal plain
Red Sea
Farasan
Islands
ETHIOPIA
YEMEN

Figure 19

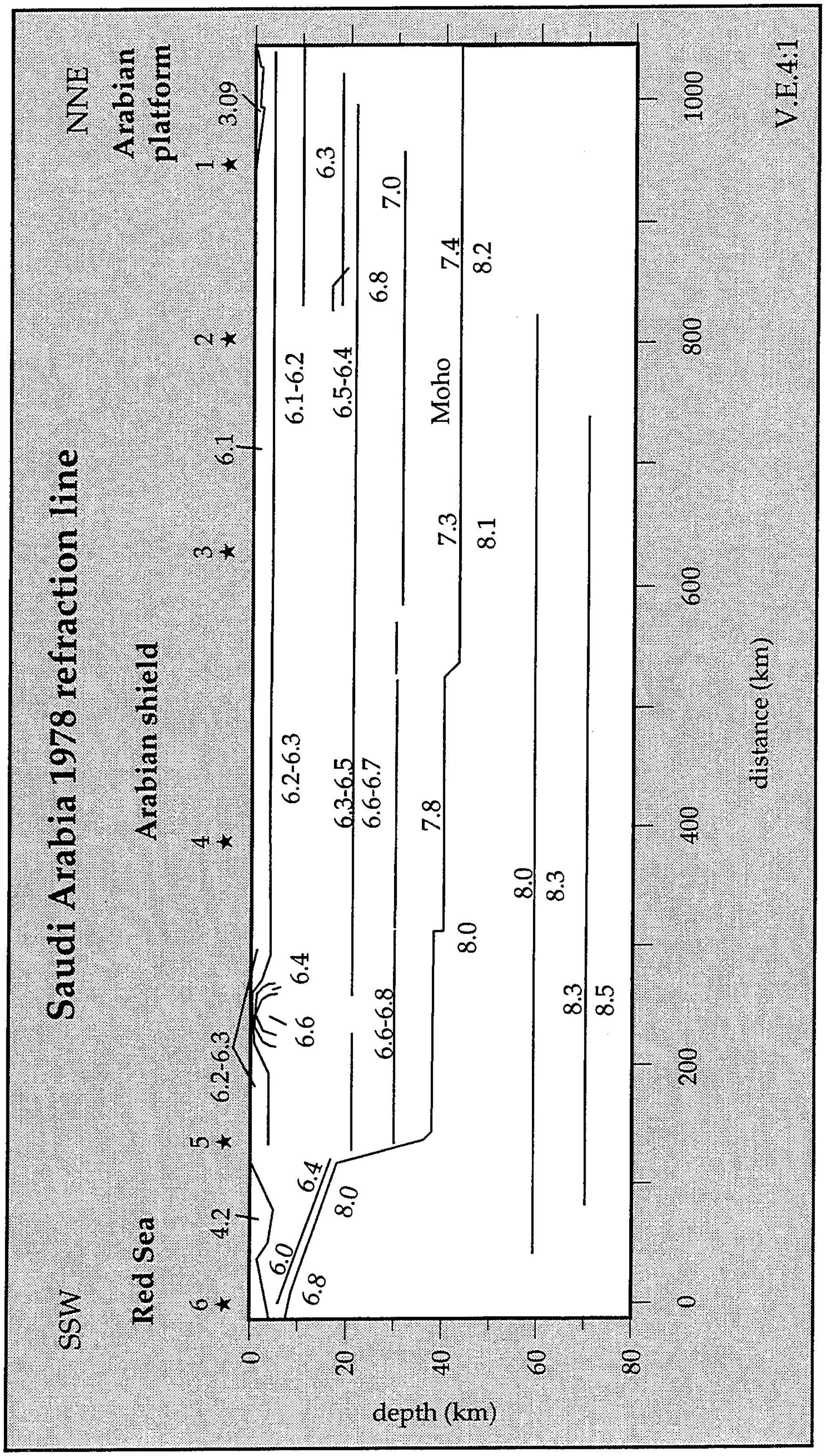
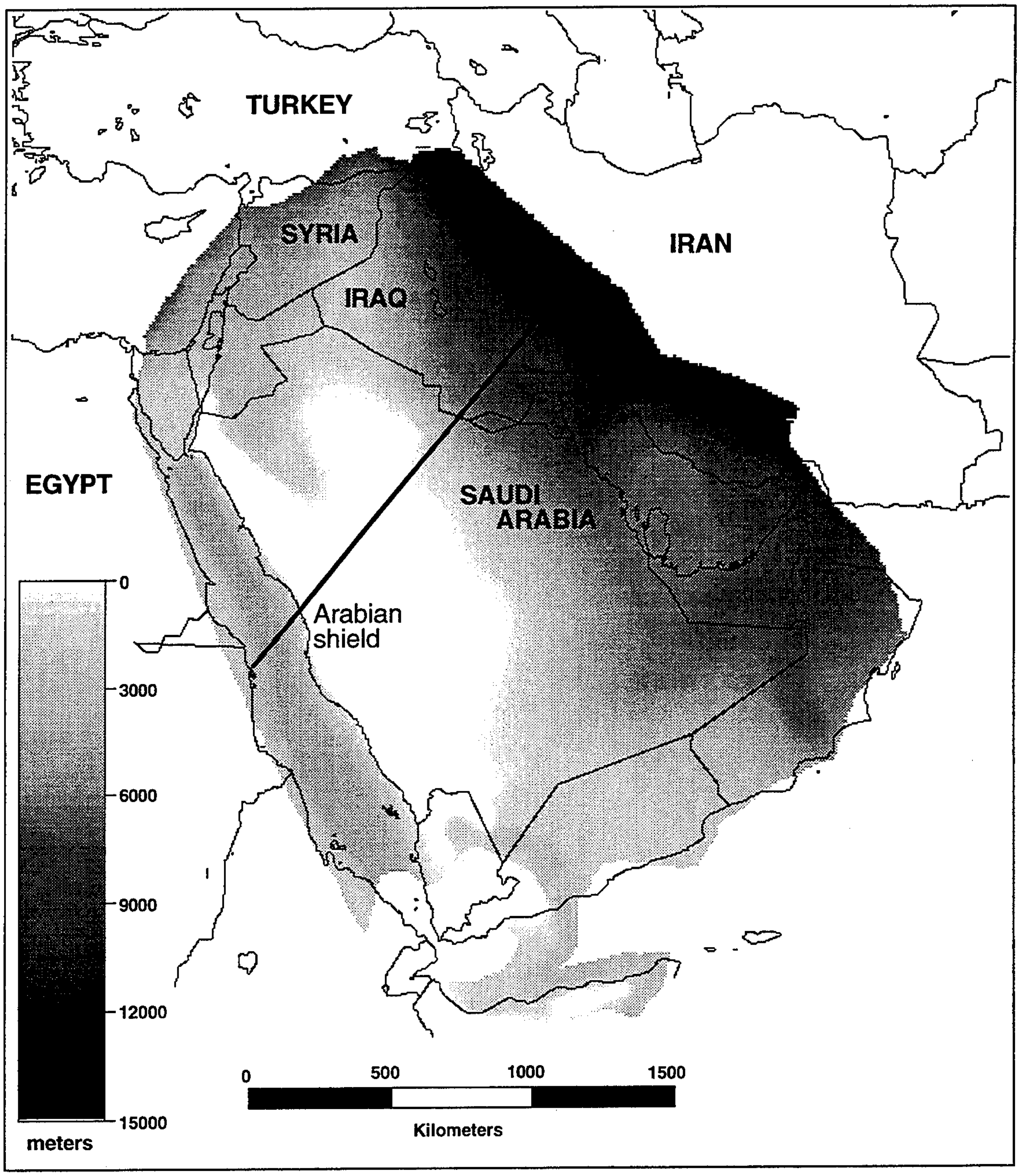

Saudi Arabia 1978 refraction line
SSW
NNE
Red Sea
Arabian shield
Arabian platform
6
5
4
3
2
1
4.2
6.2-6.3
6.1
3.09
6.0
6.8
6.4
8.0
6.6
6.4
6.6-6.8
6.2-6.3
6.3-6.5
6.6-6.7
7.8
8.0
8.0
8.3
8.3
8.5
7.3
8.1
6.1-6.2
6.5-6.4
Moho
6.8
7.4
8.2
6.3
7.0
depth (km)
0
20
40
60
80
distance (km)
0
200
400
600
800
1000
V.E.4:1

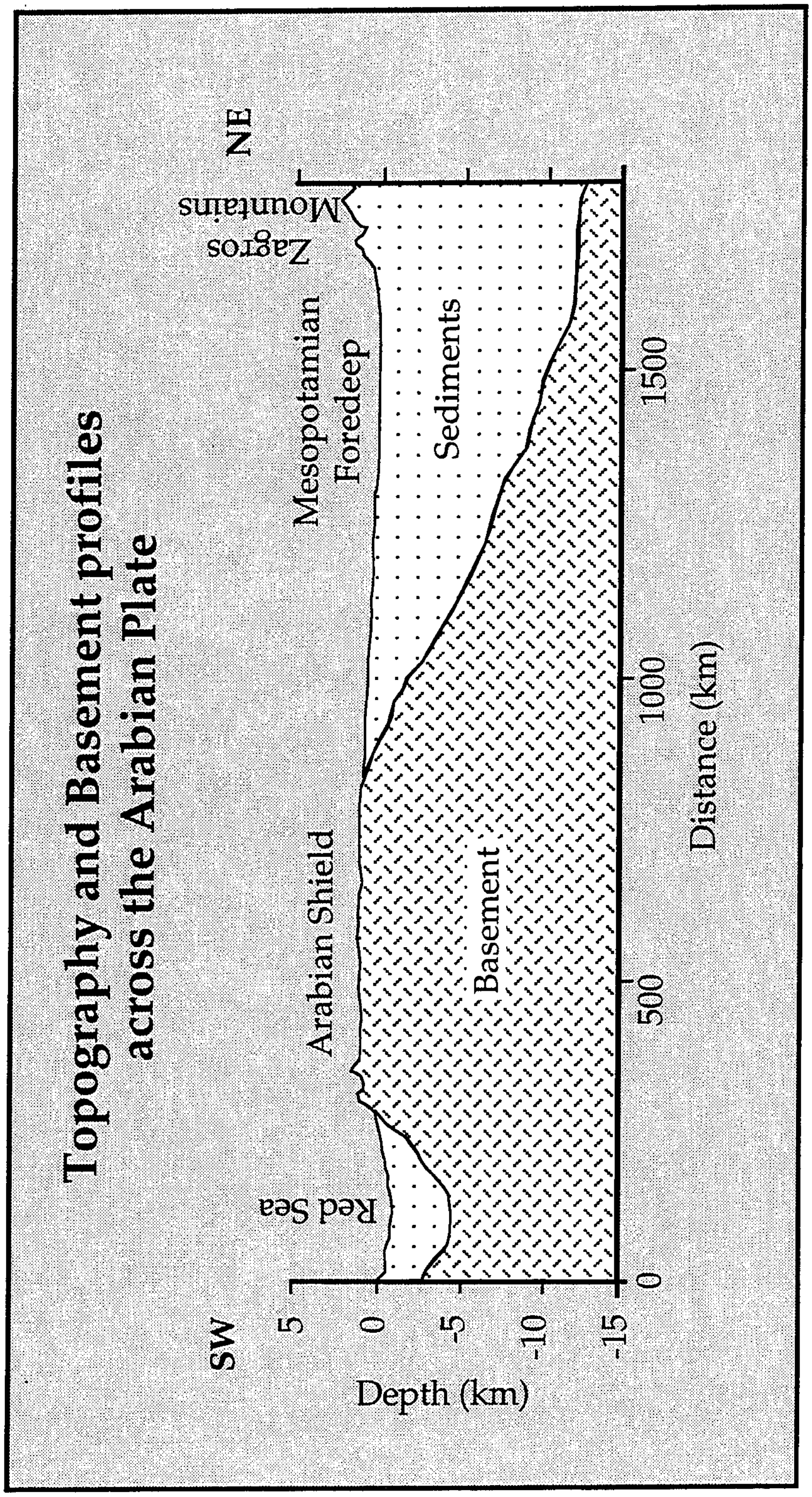
Figure 20

Middle East thickness of sedimentary cover



Transverse Mercator projection

Figure 21



Topography and Basement profiles across the Arabian Plate
SW
NE
Depth (km)
5
0
-5
-10
-15
Red Sea
Arabian Shield
Mesopotamian Foredeep
Zagros Mountains
Sediments
Basement
0
500
1000
1500
Distance (km)

Figure 22

APPENDIX I: FILE FORMATS

This is a description of the formats of the files from release #2 on our anonymous FTP server. Please address all questions, comments, and suggestions on the format and content of our network database to "seber@geology.cornell.edu".

Figures

The PostScript files (with the ".ps" suffix) are for the figures contained in this report and can be printed on PostScript printers. These files were created by Adobe Illustrator v. 3.5 and conform to Adobe PostScript standard v. 3.

The Adobe Illustrator files (with the ".ai" suffix) are for the same figures and can be read by drawing and page layout programs that can handle Illustrator v. 3 format files, including Adobe Illustrator v. 3.5 available for Sun workstations.

Data Files

The raw data files, extracted from Arc/Info, have several different flat ASCII formats for different types of information, and the file formats are explained below and in "README" files for each type available on the FTP server.

Line files

The files with the ".line" suffix contain "arcs" or line data such as refraction line locations or crustal interfaces. These files were extracted from Arc/Info with the `UNGENERATE LINE` command, and can be reloaded into Arc/Info with the `GENERATE` and `LINE` commands. The lines are stored with an arc ID number for each line and a list of coordinates for the vertices along the line. The coordinates

are either in "geographic" latitude-longitude coordinates in decimal degrees (denoted ".dd.line") or in distance-depth coordinates in km (denoted ".km.line"), with depth positive upward and negative below sea level. The line files look like this *(italics indicates comments)*:

arcID *(integer)*
x1 *(longitude or distance)*, y1 *(latitude or elevation) (floats)*
x2, y2
.
.
.
xn, yn
END *(end of this line)*
arcID
x1, y1
...
xn, yn
END
END *(end of file)*

Point files

The files with the ".point" suffix contain point data such as shot-point locations or Moho depth points. These files were extracted from Arc/Info with the `UNGENERATE POINT` command, and can be reloaded into Arc/Info with the `GENERATE` and `POINT` commands. The points are stored with a point ID number and coordinates for each point. The coordinates are either in "geographic" latitude-longitude coordinates in decimal degrees (denoted ".dd.point") or in distance-depth coordinates in km (denoted ".km.point"), with depth positive upward and negative below sea level. The point files look like this *(italics indicates comments)*:

pointID *(integer)*, x1 *(longitude or distance)*, y1 *(latitude or elevation) (floats)*
pointID, x2, y2
...
pointID, xn, yn
END *(end of file)*

AAT files

The files with the ".aat" suffix contain arc attribute data such as velocities above and below crustal interfaces. These files are a simple ASCII listing of the

AAT (Arc Attribute Table) in Arc/Info. They were created with the `PRINT` command in INFO, and can be loaded with the `ADD FROM` command of INFO. The AAT files for the 2-D crustal sections (.km.aat suffix) contain the P velocities in km/s (for refraction profiles) or densities in g/cm^3 (for gravity profiles) for each interface (referenced according to the arcID) in the following format:

arcID *(integer)* vel_above vel_below *(floats)* *for refraction profiles*

arcID *(integer)* dens_above dens_below *(floats)* *for gravity profiles*

...

The AAT files for the contour line maps (.dd.aat suffix) contain the depths or thicknesses for the interface or layer in km. The arcID is again used for reference, but in this case the arcID may not be unique because it is usually set to an integer version of the depth (multiplied times 10 if the contours do not have integer intervals). Depths are negative below sea level. The file has the following format:

arcID *(integer)* depth (*or thickness) (float)*

...

APPENDIX II: RELEASE #1
PRIORITY LIST

The following is a brief outline of the planned datasets to be made available to ARPA/AFOSR/DOE/AFTAC research community and any other interested researchers. The items are listed in order of decreasing priority, based on our perception and ARPA of the most immediate data needs. The crustal structure databases seems to be the most useful to a wide variety of studies and are put at the top of the list.

Crustal Structure Databases

Depth to Moho map

<u>refraction</u>

Egypt
Iran
Israel
Jordan
Mediterranean
Morocco
Red Sea
Saudi Arabia
Tunisia

<u>gravity</u>

Egypt
Iran
Iraq
Israel
Jordan
Lebanon
Mediterranean
Morocco
Red Sea
Saudi Arabia
Syria

Depth to basement map

Most of the following types of data are available for the Middle East and North Africa, however resolution and quality varies widely across the area.

<u>refraction</u>
<u>well data</u>
<u>geological mapping</u>

gravity
reflection
magnetics

Velocity profiles

Mainly based on refraction profiles and also some surface wave studies.

Lg propagation

Bibliography

A comprehensive listing of references on the area is available at Cornell and is being entered into a database system on the Macintosh (HyperCard). Printouts can be made in a variety of formats with various search parameters.

Other Digital Databases

Landsat MSS imagery

Morocco
Syria
Lebanon
Israel-partial
Iraq-partial
Jordan-partial
Turkey-partial

Locations of explosions

Morocco
Jordan
Syria
Saudi Arabia

Middle East and North Africa EQ catalog

local and international network locations 1900–1989

Gravity

Syria

<u>Lebanon</u>
<u>Morocco</u>
<u>Israel</u>
<u>Egypt</u>

Focal mechanism catalog
<u>extensive listings since 1960's to be entered into digital form</u>

Earthquake waveforms

Upper Mantle Structure

Pn mapping and Pn tomography

Sn propagation

Surface wave studies

Body wave inversion

Q and attenuation studies

Locations and Other Parameters of Seismic Stations

Morocco network

Syria network

Jordan network

Israel network

Saudi network

Regional Geoscience Transect Sections and Maps

APPENDIX III
BIBLIOGRAPHY OF THE MIDDLE EAST AND NORTH AMERICA

MARCH 1995

Note that this is a preliminary release, and we will be improving and updating this bibliography with time. New versions will supersede this version in the future. The references have been separated into four categories below: Middle East Geology, Middle East Geophysics, North Africa Geology, and North Africa Geophysics.

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